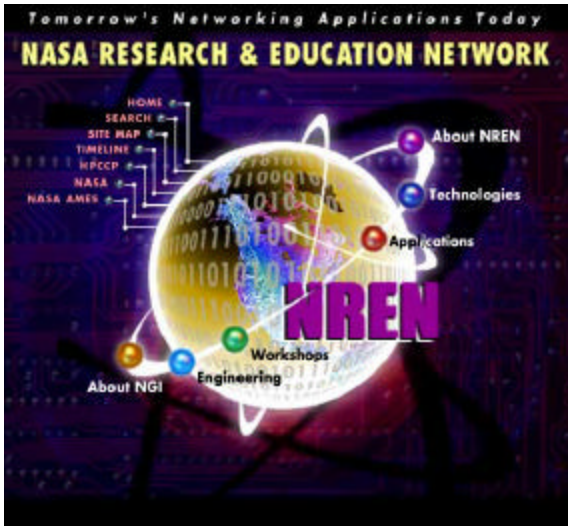
HPCC Independent Assessment

NASA Research and Education Network



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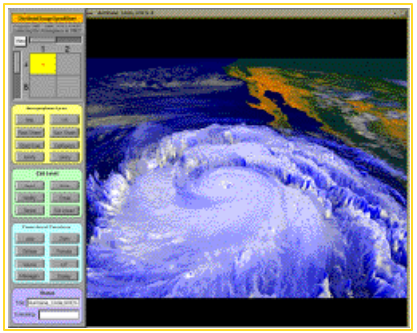
June 2000

NASA Ames Research Center

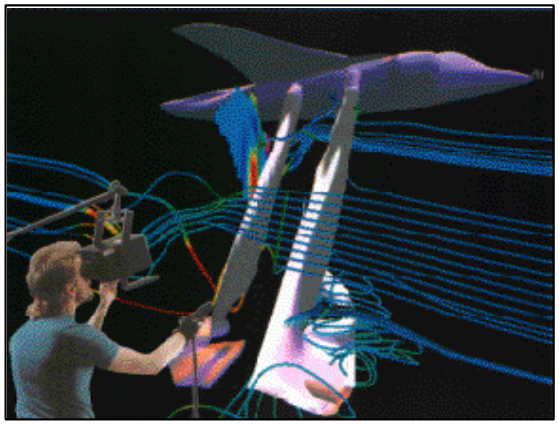
Presentation Outline

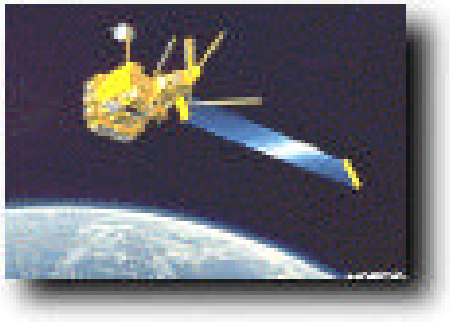
- Networking Vision
- Project Goal
- Project Objectives
- Changes from Phase I to Phase II
- Implementation approach
- Organization chart
- Milestones
  - Flow chart
  - Phase I milestones
    - Current status
    - Phase I milestone accomplishments
    - Milestones rolled from Phase I to Phase II
  - Phase II milestones
- Resources
  - Civil Servant Workforce
  - Budget

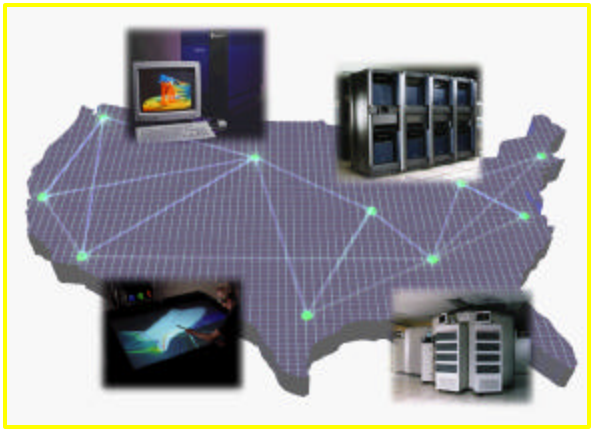
Project Vision



Change the future of networking and networking applications







Overall Project Goal

- **NREN's goal is to extend U.S. technological leadership in computer communications through research and development that advances leading-edge networking technology and services.**

- **Furthermore, NREN will then apply these enhanced capabilities to NASA mission and educational services.**

Project Objectives

- **Customer Impact Objective**
  - *Infuse emerging networking technologies into NASA mission-critical applications*
- **Communications Performance Objective**
  - *Dramatically increase communications performance available for use in meeting NASA mission requirements*
- **Interoperability Objective**
  - *Dramatically increase the interoperability of application and system software operating on high-performance computing and communications systems available for use in meeting NASA mission requirements*
- **Portability Objective**
  - *Dramatically improve the portability of application software and data to new or reconfigured high-performance computing and communications systems available for use in meeting NASA mission requirements*

Project Objectives

- **Reliability Objective**
  - *Dramatically improve the reliability of user-requested events executing on high-performance communications systems available for use in meeting NASA mission requirements*

- **Resource Management Objective**
  - *Dramatically improve the ability to manage heterogeneous and distributed high-performance networking resources available for use in meeting NASA mission requirements*

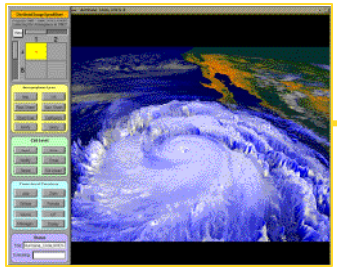
- **Customer Usability Objective**
  - *Dramatically improve the usability of high-performance computing and communications tools and techniques available for use in meeting NASA mission requirements*

Change from Phase 1 to Phase 2 Objectives

- **Customer focus closely aligned with HPCC customer base**
  - **Aerospace**
  - **Earth Science**
  - **Space Science**
- **Addition of Resource Management Objective**
  - **Studies in allocation of network resources**
  - **Merging of resource management objectives with Quality of Service technologies**
- **Deletion of Scalability Objective**
  - **Discontinuation of Internet Protocol version 6 (IPv6) efforts (unable to align work with HPCC customer goals)**

Approach

NASA Mission Applications



Earth Sciences:
Advanced Earth Sciences Investigations

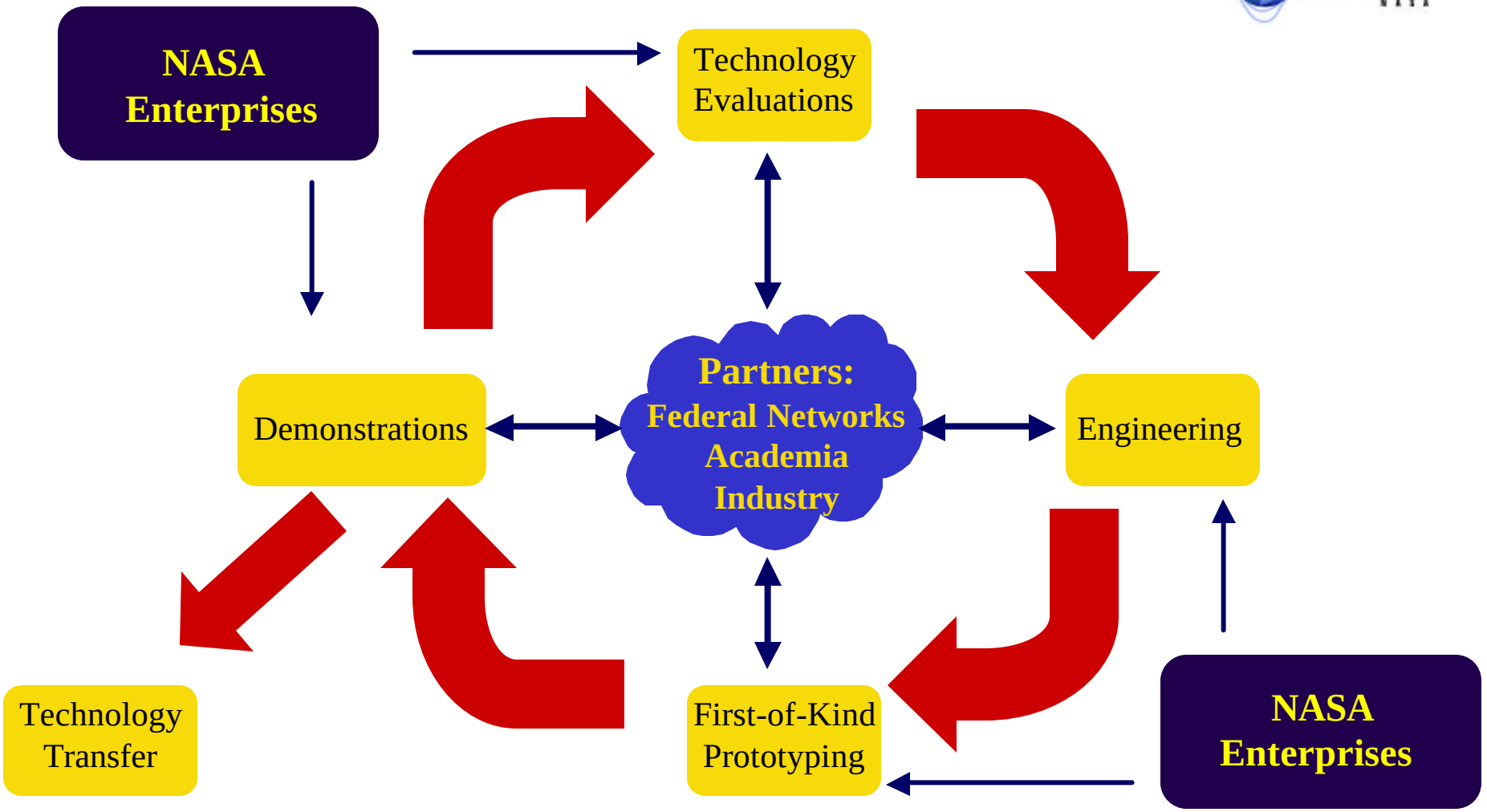
Accelerate network technology development to meet NASA unique mission requirements today.

Space Exploration:
Telescience and Interplanetary Internet

Human Exploration and Development of Space:
International Space Station

Advanced Aerospace Tools & Design: Aviation Safety, Wind Tunnels on-line, Virtual Flight Simulation Laboratories

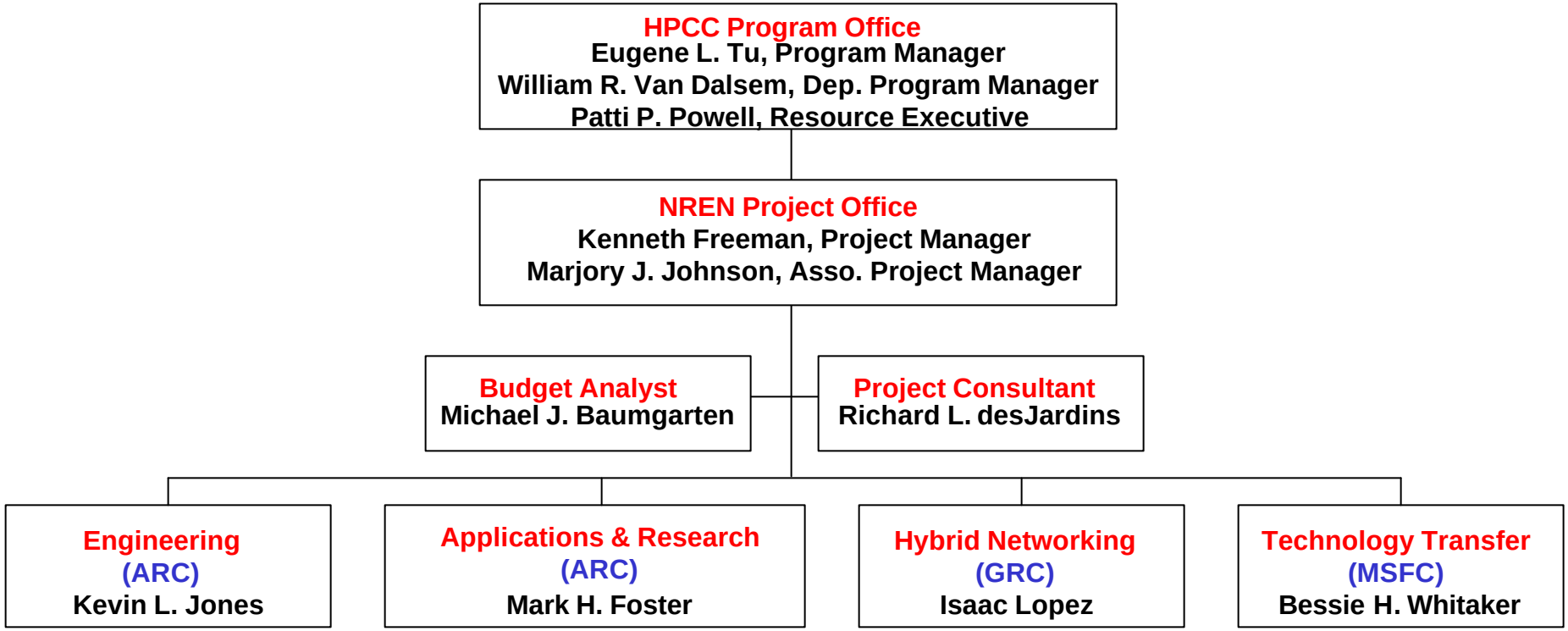
Approach



NREN Approach : Accelerate network technology development to meet NASA unique mission requirements today.

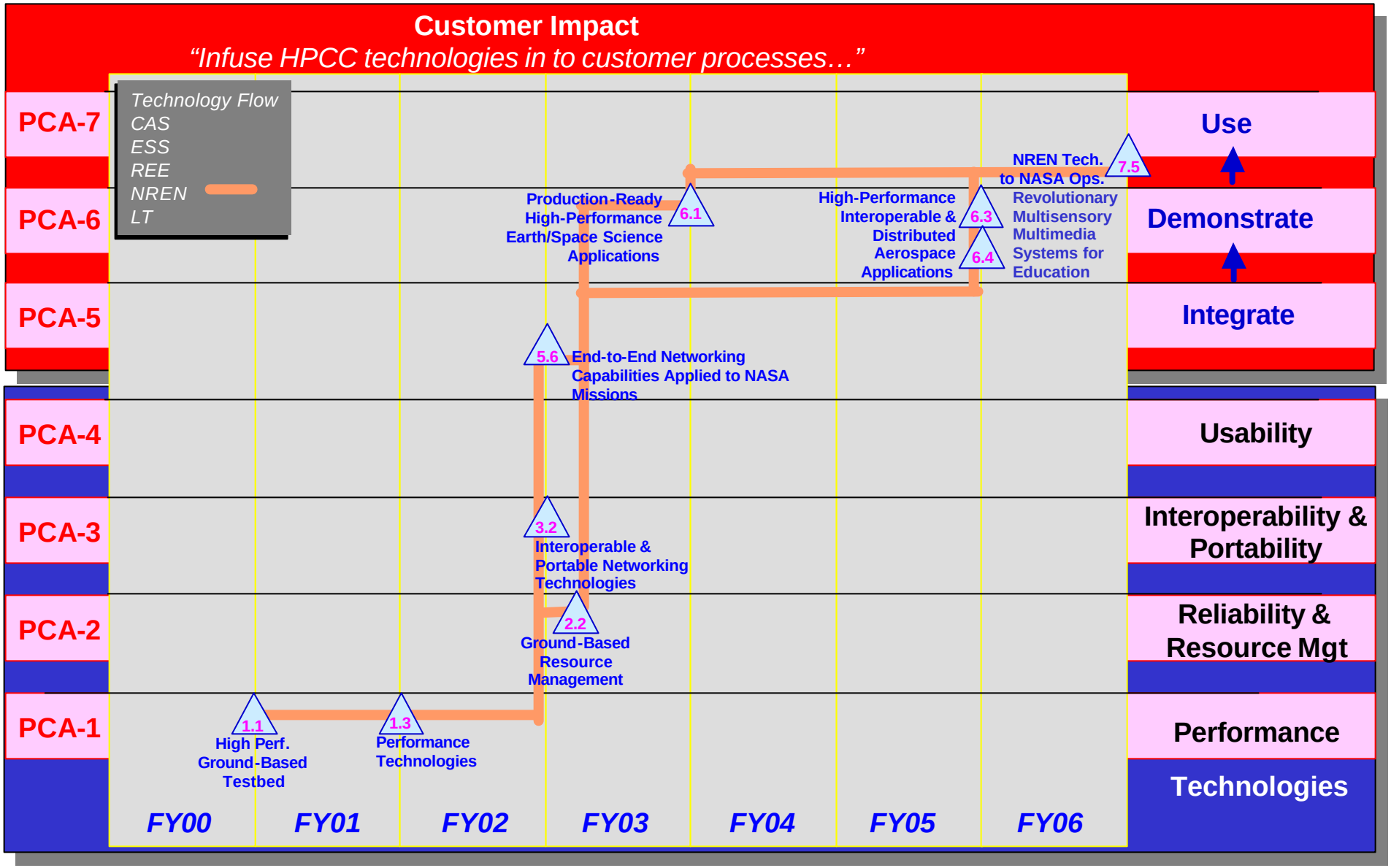
Project Structure

Organization Structure



NREN Project Goals and Milestones

- Technology Flow -



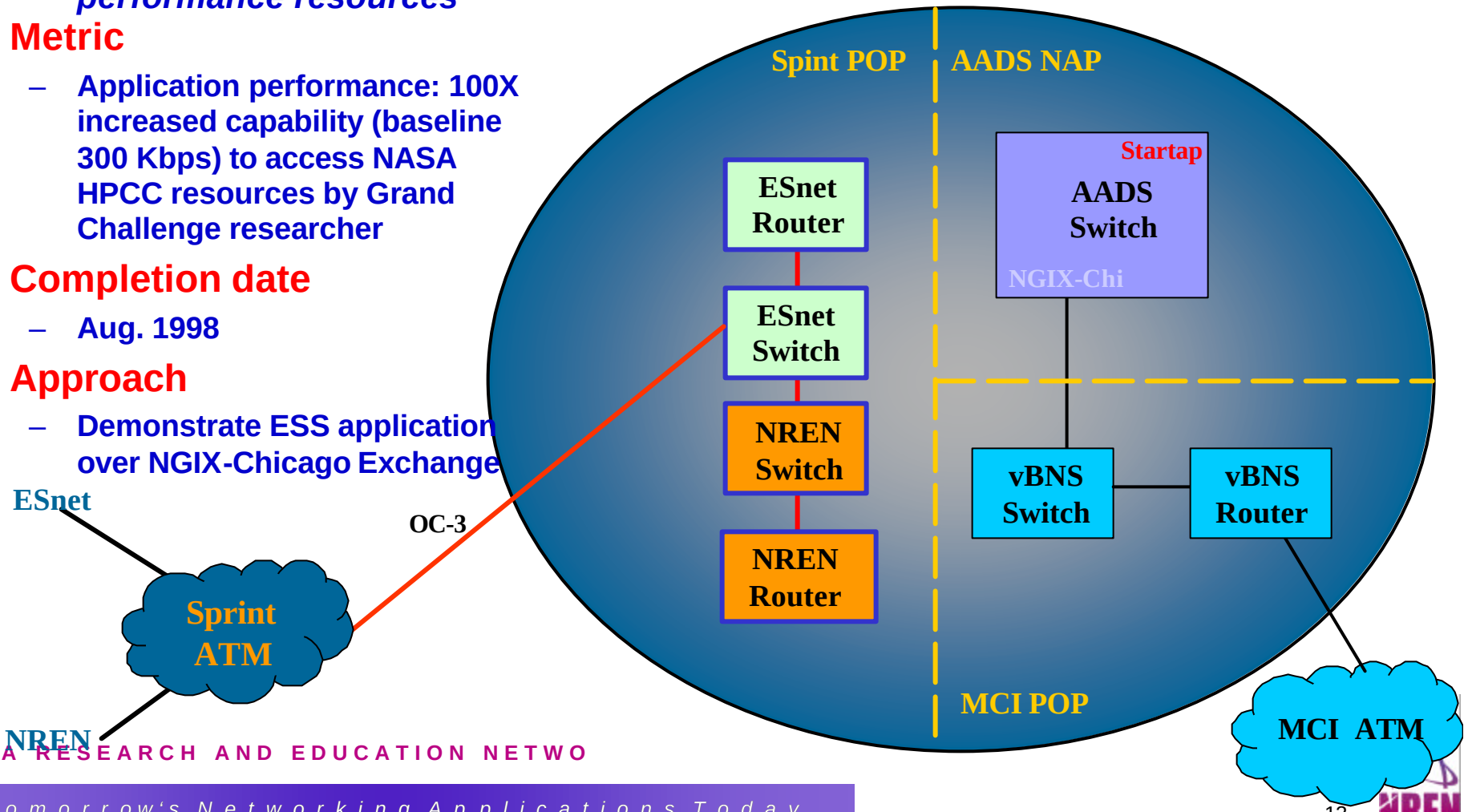
Phase 1 Milestones

NASA Research and Education Network Milestones			
#	Due Date	Comp. Date	IAR Review
NR1	6/93	6/93	Prior IAR
NR2	9/94	12/94	Prior IAR
NR3	6/95	9/95	Prior IAR
NR4	9/95	9/95	Prior IAR
NR5	3/96	3/96	Prior IAR
NR6	9/97	9/97	Prior IAR
NR7	10/98	10/98	IAR2000-Phase I
NR8	3/00	11/99	IAR2000-Phase I
NR9	9/02		IAR2000-Phase II
NR11	6/04		IAR2000-Phase II

Black:	Milestones completed prior to last IAR
Red:	Milestones completed since last IAR
Blue:	Milestones rolled over to Phase II

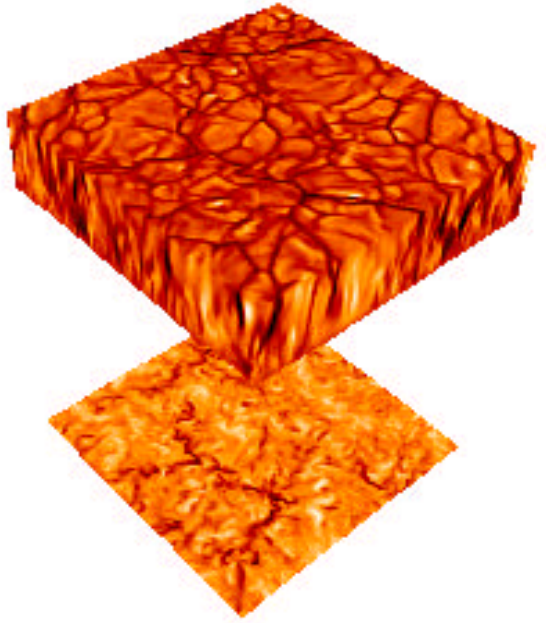
Accomplishments: Completed Milestones (NR-7)

- **Milestone (NR-7)**
  - ***Establish next generation internetwork exchange to connect Grand Challenge universities' principal investigators to NASA high performance resources***
- **Metric**
  - **Application performance: 100X increased capability (baseline 300 Kbps) to access NASA HPCC resources by Grand Challenge researcher**
- **Completion date**
  - **Aug. 1998**
- **Approach**
  - **Demonstrate ESS application over NGIX-Chicago Exchange**



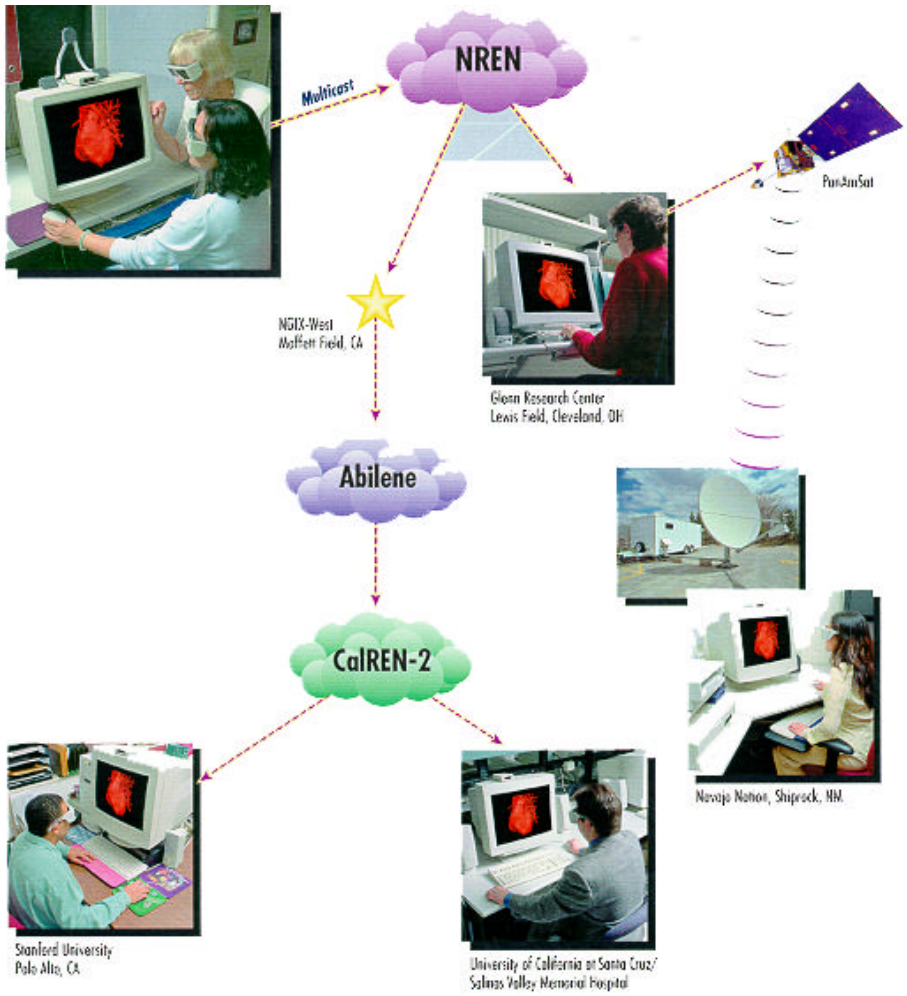
Accomplishments: Completed Milestones (NR-7)

- **Application Demonstration**
  - Successfully prototyped Turbulent Convection and Dynamos in Stars, an HPCC ESS Grand Challenge application, across three high performance wide area research networks via the Next Generation Internet Exchange in Chicago.
  - This application allowed researchers to collaborate on volume-rendered data sets in real time.
  - The location doing the rendering sees the data in 3 dimensions while the remote sites see a 2-dimensional image.
- **Bandwidth Achieved**
  - 40 Mbps
- **Major Partners**
  - NASA GSFC / ESS
  - NSF: very high performance Backbone Network Service (vBNS)
  - University of Colorado
  - University of Minnesota
- **Completed: August 1998**

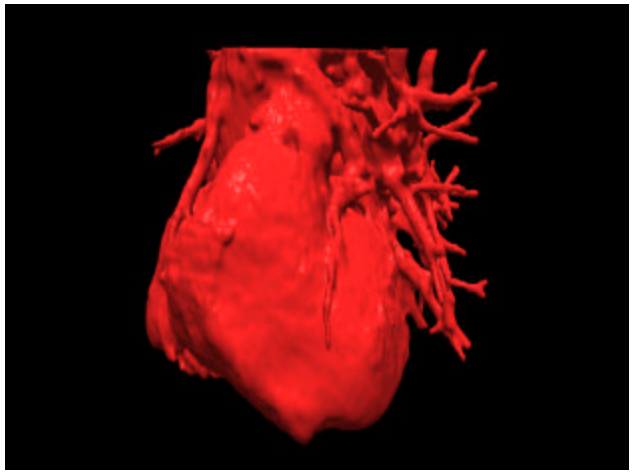


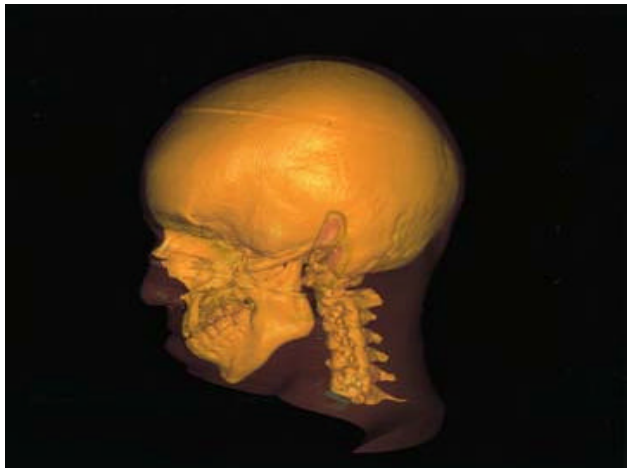
Accomplishments: Completed Milestones (NR-8)

- **Milestone (NR-8)**
  - Demonstrate 500 times end-to-end performance improvement of Grand Challenge and/or NASA mission applications based on FY 1996 performance
- **FY'96 Performance Baseline**
  - 300 kbps
- **Application**
  - Virtual Collaborative Clinic
- **NREN Technology**
  - Multicast
- **Completed: November 1999**



Accomplishments: Completed Milestones (NR-8)





Result of Demonstration

- Topology of the Virtual Collaborative Clinic demonstration utilizing a higher performance testbed to allow colleagues in the medical arena to simultaneously review medical images remotely in real time.

Accomplishment/Relationship to Milestone :

- Achieved between 60-90 Mbps within lab and 50 Mbps over NREN infrastructure
- Multicast bandwidth of ~24 Mbps end-to-end from source at NASA ARC to all destinations with less than 1% loss (700% performance increase over current baseline)
- Infused network technology into a telemedicine application
- Peered with other diverse high-performance wide area networks via NGIX-West
- Collaboration between NASA centers, academia and industry
- Implemented multicast research results over multiple NGI networks
- Engineered a hybrid network including satellite transmission between ARC and Northern Navajo Nation Medical Center in Shiprock, NM
- Demonstrated aggregate bandwidth of 175 Mbps to geographically diverse end-sites

Rollover of Phase I Milestone to Phase II

Phase I

NR9		Due	Metric	Criteria
	Demonstrate high performance network applications across interagency high performance testbed using NASA NREN	9/02	# application demonstrations Application performance	10+ demos 100-500 times or more end-to-end performance improvement

Phase II

Two application demonstrations have been completed:

- Turbulent Convection and Dynamos in Stars: August 1998
- Virtual Collaborative Clinic: May 1999

Remainder of the metric will be met according to the table below.

HPCC Milestones	Project Milestones	Due Dates
1.3	NR-1.3.3 NR-1.3.4	3/01 9/01
5.6	NR-5.6.1 NR-5.6.2 NR-5.6.3 NR-5.6.5 NR-5.6.6	9/00 3/01 9/01 3/02 9/02
6.1	NR-6.1.1	9/02

Rollover of Phase I Milestone to Phase II

Phase I

NR-11		Due	Metrics	Criteria
	Demonstrate Middleware Enhanced Network across NASA capable of near real time networking environments for distributed collaborations	6/04	- Number of application demonstrations - Scalability and application performance	- At least 2 demonstrations - Multi-network demonstration at same or better than 2004 performance baseline

Phase II

NR-11 will be met according to the table below.

HPCC Milestones	Project Milestones	Due Dates
2.2	NR-2.2.2 NR-2.2.4	9/01 12/02

Technology Matrix

TECHNOLOGIES	PCA 1	PCA 2	PCA 3	PCA 5	PCA 6	PCA 7
Gigabit Networking	X			X	X	X
Multicast	X		X	X	X	X
Quality of Service	X	X	X	X	X	X
Adaptive Middleware		X		X	X	X
Hybrid Networking	X				X	X
Traffic Engineering			X		X	X

PCA 1: Component Technologies for Performance

Program and Project Milestones

		Planned Completion
HPCC 1.1: Establish high-performance testbed for application performance		**09/00**
NR-1.1.1	ARC connected to support WAN gigabit testbed	07/00
NR-1.1.2	Performance testing confirming gigabit WAN capability at 3 locations	09/00
HPCC 1.3: Develop and apply technologies to measure and enhance performance on high-performance testbeds		**09/01**
NR-1.3.1	Demonstration of measurement of preferential flow in the lab environment	06/00
NR-1.3.2	Demonstration of measurement of preferential flow across the WAN environment	09/00
NR-1.3.3	Insert multicast capability into 1 application involving distribution of Earth science data	03/01
NR-1.3.4	Insert multicast capability into 1 application involving collaborative aerospace application	09/01

PCA 1

NASA Research & Education Network

NREN

Gigabit Networking

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Gigabit Networking*

- **Definition**
  - **End-to-end solutions for distributed applications that require at least 500 Mbps to the desktop**
- **Objective**
  - **Enable high-speed applications**
- **Status**
  - **Current operational end-to-end networking speed is 5-70 Mbps**
  - **Bandwidth connectivity at selected NASA sites**
    - GSFC: 2 Gbps
    - ARC: 622 Mbps
    - JPL: 622 Mbps
- **Partnerships**
  - **DARPA (NTON and ATDnet)**

PCA 1: Component Technologies for Performance

HPCC NASA

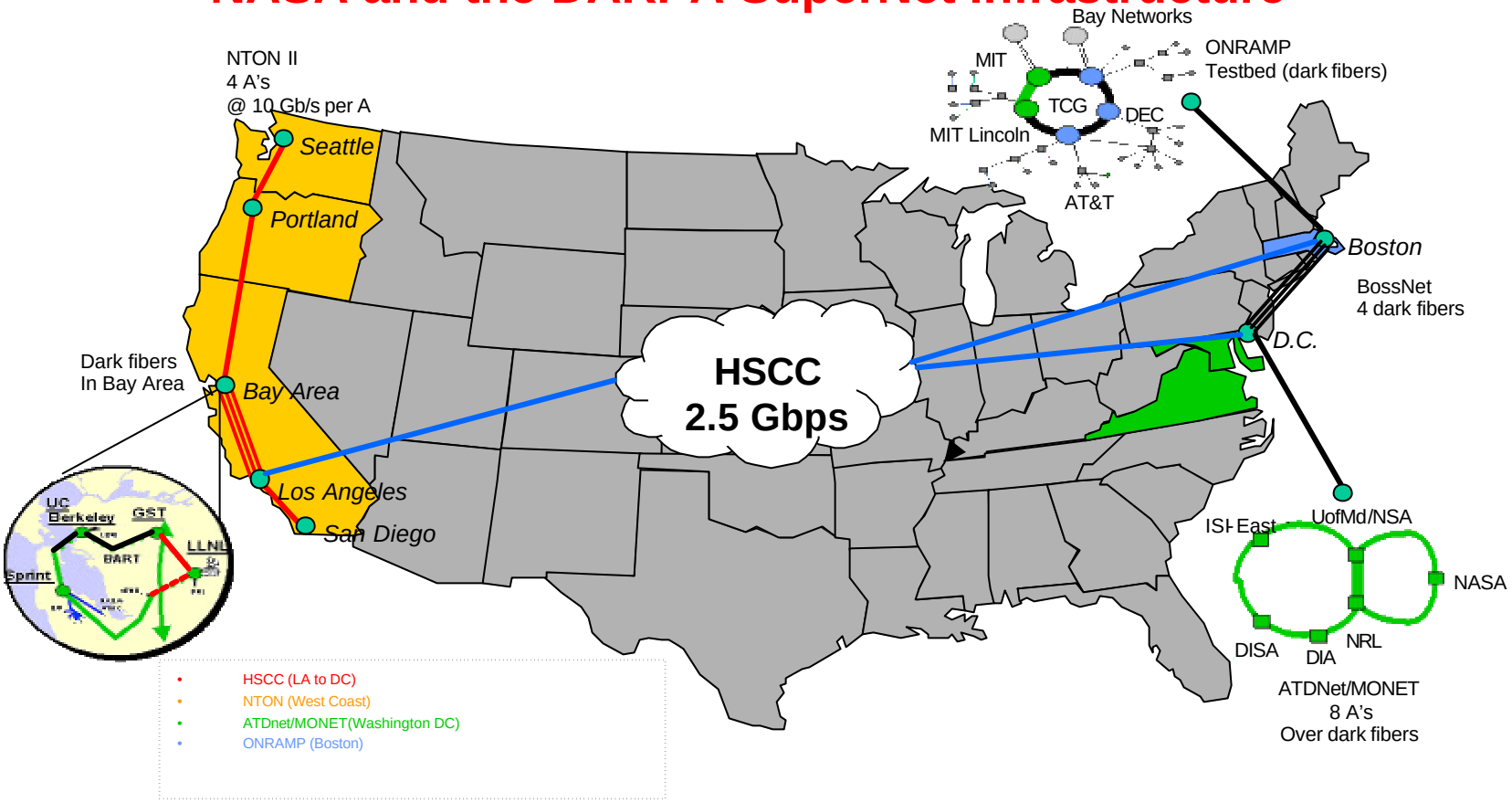
Technology: *Gigabit Networking*

- **Project Milestones Supporting PCA 1**
  - **HPCC 1.1: Establish high-performance testbed for application performance (09/00)**
    - ARC connected to support WAN gigabit testbed (NR-1.1.1: 07/00)
    - Performance testing confirming gigabit WAN capability at 3 locations (NR-1.1.2: 09/00)
- **Implementation Plan**
  - **Establish OC-48 Connections (08/00)**
    - NASA Ames, NASA GSFC and JPL
    - Interconnection to NTON and ATDNet
  - **Gigabit performance testing**
    - Goal is to determine maximum achievable throughput over gigabit Ethernet, OC-12 POS, and OC-12 ATM
    - Tools for measuring performance include ttcp, iperf, and gen_send/gen_rec

PCA 1: Component Technologies for Performance

Technology: *Gigabit Networking*

NASA and the DARPA SuperNet Infrastructure



PCA 1

NREN

NASA Research & Education Network

Hybrid Networking

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Hybrid Networking*

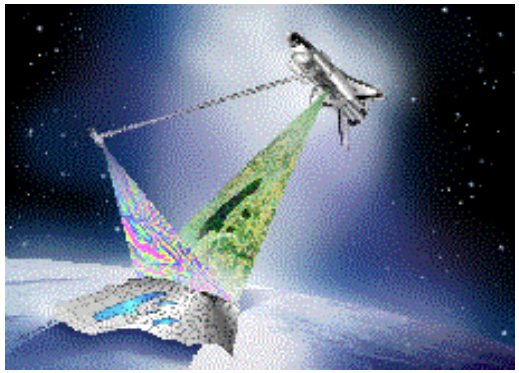
- **Definition**
  - **Hybrid networking technologies enable seamless integration of satellite and terrestrial networks.**
- **Objective**
  - **Enable access to remote sites or to sites that do not have high speed terrestrial connectivity.**
- **Status**
  - **Traditional network protocols may require modification to enhance performance in this high-latency, lossy network environment.**
- **Implementation Plan**
  - **Conducted Trans-Atlantic Demonstration, March 2000**
  - **Trans-Pacific Demonstration scheduled to begin May 2000**

PCA 1: Component Technologies for Performance

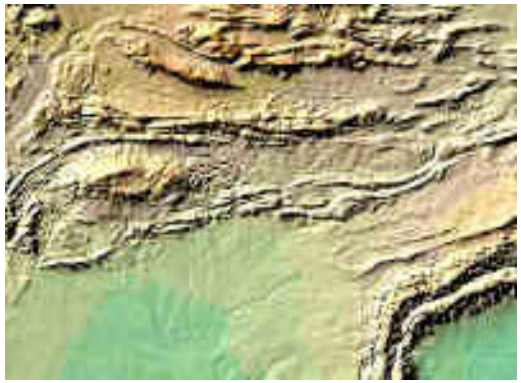
Technology: *Hybrid Networking*

Trans-Atlantic Demonstration: Data Distribution from Shuttle Radar Topography Mission

- **Goal**
  - Demonstrate international distribution of large data files using hybrid networking
- **Partners**
  - NASA JPL, NASA GRC, German Aerospace Center (DLR)
- **NREN Data Distribution Experiment**
  - Download topographic data to JPL from satellite
  - DLR periodically initiate file transfer over NREN from JPL to GRC
  - Transmit files from GRC to DLR via transatlantic satellite link, utilizing StarBurst OmniCast content distribution protocol to ensure guaranteed, reliable distribution over UDP
- **Significance**
  - Validates use of hybrid networking for global interconnectivity
  - Validates the effectiveness of a data transfer approach based on UDP, thus eliminating the excessive round-trip delay required for TCP acknowledgements in a satellite environment (achieved data rates were approximately 12 Mbps)



Radar beams sweep Earth's surface collecting data



Mountain Range in the border area Pakistan / Afghanistan

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Hybrid Networking*

Trans-Pacific Demonstration: Visible Human

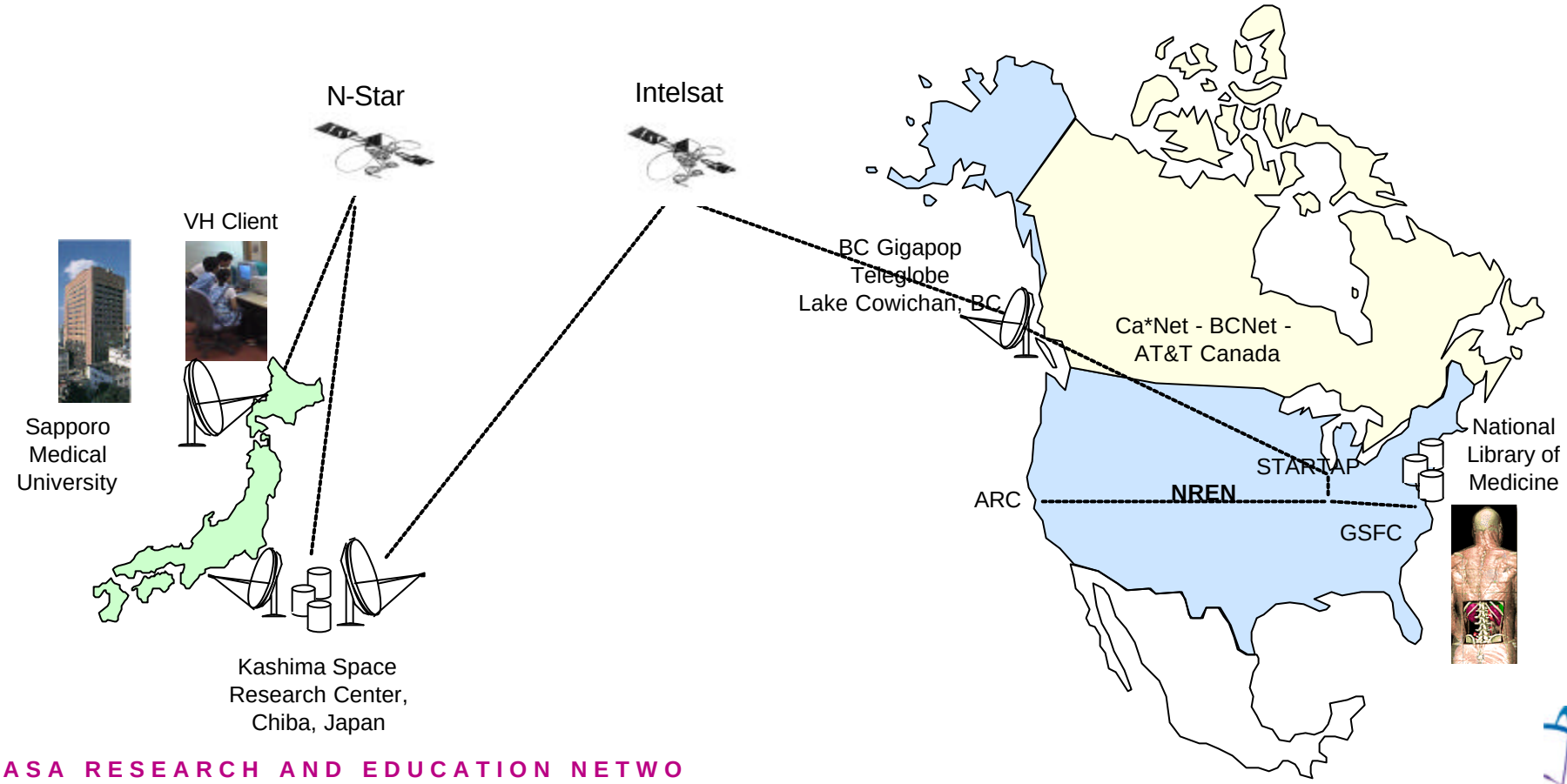
- **Goal**
  - Demonstrate interactive international access to large data sets
  - Investigate use of distributed file system over hybrid networks
  - Investigate impact of double-hop satellite on application performance

- **Partners**
  - NASA GSFC, National Library of Medicine, Sapporo Medical University, Japan Communications Research Laboratory, Intelsat, Teleglobe, AT&T Canada, CA*Net3, BCNet, APAN/TransPAC

PCA 1: Component Technologies for Performance

Technology: *Hybrid Networking*

Trans-Pacific Demonstration: Visible Human



PCA 1

NASA Research & Education Network

NREN

Quality of Service

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Quality of Service (QoS)*

- **Definition**
  - Quality of Service technologies provide the ability to partition network resources and to control various attributes of network service received by an application
  - QoS requirements are typically expressed in terms of bandwidth, latency, packet loss probability, jitter
  - Network Classes of Service: Best Effort, Expedited / Assured Forwarding
- **Objective**
  - Protect general (best effort) network users from resource intensive applications
  - Enable applications that cannot run effectively across best effort NASA networks today
- **Status**
  - Currently all network traffic is “best effort”—i.e., it is not possible to provide any assurance that an application will have access to network resources at a given time
  - Active research area in the Internet community
  - Several experimental QoS testbeds

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Quality of Service (QoS)*

- **Project Milestones Supporting PCA 1**
  - **HPCC 1.3: Develop and apply technologies to measure and enhance performance on high-performance testbeds (09/01)**
    - Demonstration of measurement of preferential flow in the lab environment (NR-1.3.1: 06/00)
    - Demonstration of measurement of preferential flow across the WAN environment (NR-1.3.2: 09/00)
- **Implementation Plan**
  - **NREN is developing a tool called PCMon for measuring multiple service classes**

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Quality of Service (QoS)*

- **PCMon objective**
  - Monitor IP traffic subjected to preferential treatment
  - Architect and deploy a QoS monitoring and measurement system at NASA sites and exchange points
  - Provide mechanism for long-duration measurements (hours and days)
  - Develop general solution with applicability to QoS-based projects, such as the Molecular Modeling application for Astrobiology.
- **PCMon Status**
  - Deployed at Chicago STARTAP, NASA Glenn
  - Completed validation of basic functionalities: Remote access to monitors, NeTraMet packet capture, remote control/collection

PCA 1

NREN

NASA Research & Education Network

Multicast

PCA 1: Component Technologies for Performance

Technology: *Multicast*

Definition

Multicast is point-to-multipoint or multipoint-to-multipoint transmission. Use of multicast technology substantially reduces bandwidth usage and end-host processing requirements, since a single packet from the sender is duplicated only when paths to reach individual end sites diverge.

Objective

Efficient use of bandwidth

Status

- **NREN carries native WAN multicast traffic**
- **NISN carries "tunnel" WAN multicast traffic to some NASA LANs**
  - Low-speed multicast only; performance rates are less than 1 Mbps and are not scalable
  - Standardized protocol set does not exist
- **Many NASA LANs have enabled multicast**
  - Low-speed tunneled multicast most common
  - Native multicast enabled at some centers
- **NREN exploring selection of common protocol sets with external partners**

Partnerships

- **Cisco (inter-domain routing)**

PCA 1: Component Technologies for Performance

HPCC NASA

Technology: *Multicast*

- **Project Milestones Supporting PCA 1**
  - **HPCC 1.3: Develop and apply technologies to measure and enhance performance on high-performance testbeds (09/01)**
    - Insert multicast capability into 1 application involving distribution of Earth science data (NR-1.3.3: 03/01)
    - Insert multicast capability into 1 application involving collaborative aerospace application (NR-1.3.4: 09/01)
- **Implementation Plan**
  - **Demonstrated Virtual Collaborative Clinic multicast application (May 1999)**
  - **Extend multicast technologies across research networks and industry in support of NASA applications**
  - **Standardize on a common protocol set with partners**
  - **Support NASA LANs, Federal networks and Internet2 multicast implementations**
  - **Study new multicast technologies as they emerge**
  - **Discover new ways to do NASA business utilizing multicast technologies**

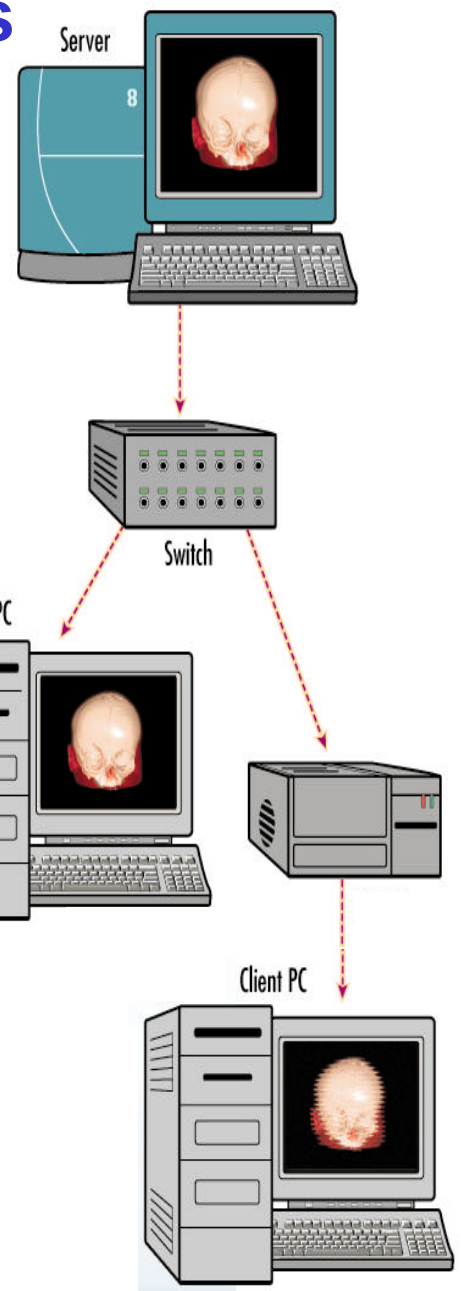
PCA 1: Component Technologies for Performance

Technology: *Multicast*

Application: Virtual Collaborative Clinic (VCC)

PCA 1: Component Technologies for Performance

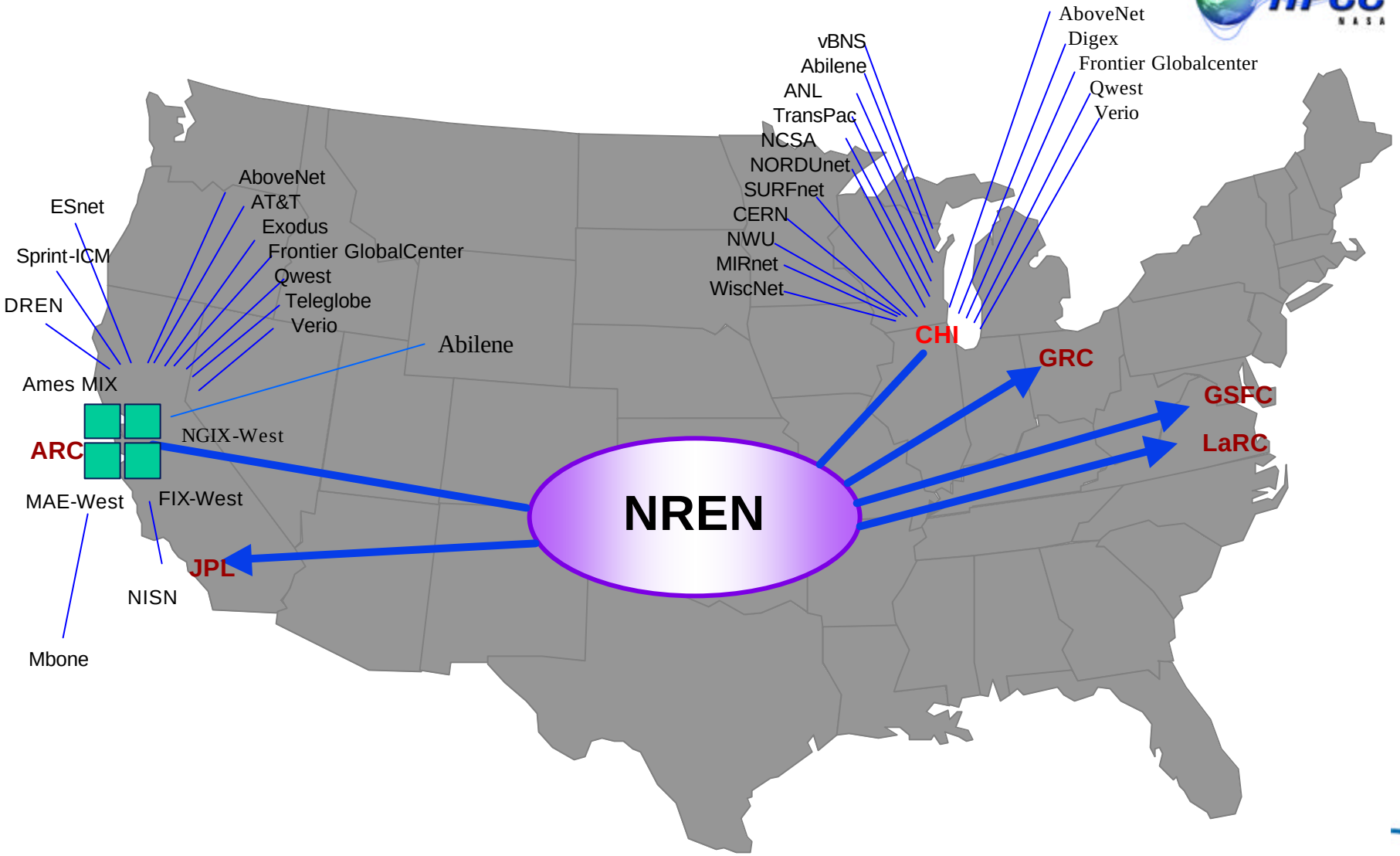
Technology: *Multicast*



Application: Virtual Collaborative Clinic (VCC)

- **Goal**
  - The Virtual Collaborative Clinic demonstrates a high performance testbed that allows colleagues in the medical arena to simultaneously view and manipulate 3-D medical images remotely in real time.
- **Network Requirements**
  - Bandwidth: 30 Mbps - 50 Mbps
  - Multicast
- **Partners**
  - Navajo Nation (New Mexico)
  - Abilene & vBNS
  - NASA Ames & NASA Glenn
  - CalREN2 GigaPOP
  - Stanford University & U.C. Santa Cruz

Current NREN Multicast Architecture



PCA 1: Component Technologies for Performance

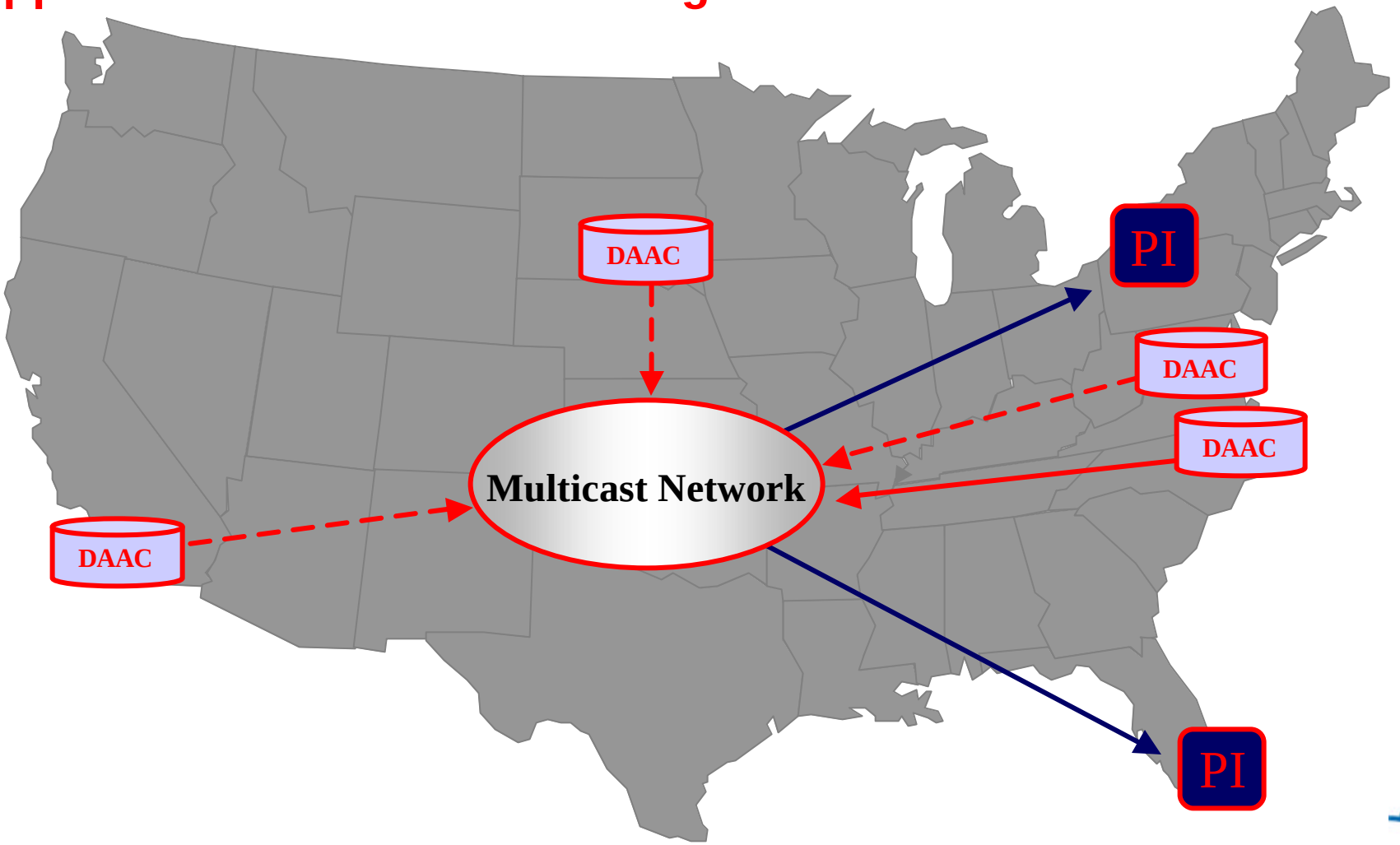
Technology: *Multicast*

Application: Distribution of Large Earth Science Data Sets

- **Application Goal**
  - Efficient, cost-effective access to large distributed data sets
- **Challenges**
  - Adapt data distribution codes to allow for multicast technologies
  - Develop a multicast solution that works for the NASA community and for external NASA PIs
- **Partners**
  - NASA Ames and NASA Goddard

PCA 1: Component Technologies for Performance

Application: Distribution of Large Earth Science Data Sets



PCA 2: Component Technologies for Reliability and Resource Management

Program and Project Milestones

		Planned Completion
HPCC 2.2:	**Develop embedded tools and services for autono resource estimation/request of local and distributed ground systems**	**12/02**
NR-2.2.1	Develop network resource management tools to provide QoS guarantees for 1 HPCC Application	01/01
NR-2.2.2	Develop mechanisms for adaptive networking capability via application resource management	09/01
NR-2.2.3	Develop network resource management tools to provide QoS guarantees for 3 HPCC Applications	06/02
NR-2.2.4	Demonstrate throughput improvement in 3 applications utilizing adaptive networking capability	12/02

PCA 2

NASA Research & Education Network

NREN

Quality of Service

PCA 2: Component Technologies for Reliability and Resource Management

HPCC NASA

Technology: *Quality of Service (QoS)*

- **Project Milestones Supporting PCA 2**
  - **HPCC 2.2: Develop embedded tools and services for autonomous resource estimation/request of local and distributed ground based systems (12/02)**
    - Develop network resource management tools to provide QoS guarantees for 1 HPCC Application (NR-2.2.1: 01/01)
    - Develop network resource management tools to provide QoS guarantees for 3 HPCC Applications (NR-2.2.3: 06/02)
- **Implementation Plan**
  - **Investigating bandwidth-reservation capabilities**
  - **Investigating use of Globus Architecture for Reservation and Allocation (GARA) to enable applications to reserve system resources, including CPU, network bandwidth, storage, etc.**
  - **Completed evaluation of router QoS mechanisms to determine ability to support reservation guarantees**
  - **Globus/GARA deployed in lab testbed**
  - **GARA wide-area testing planned between NREN lab and testbed at Argonne National Laboratory**
- **Partnerships**
  - **DOE/Argonne National Labs**

PCA 2

NASA Research & Education Network

NREN

Adaptive Middleware

PCA 2: Component Technologies for Reliability and Resource Management

HPCC NASA

Technology: *Adaptive Middleware*

- **Definition**
  - **Adaptive Middleware technologies enable distributed multimedia applications to adapt to availability of CPU and network resources, thus enabling graceful degradation under conditions of limited resources and allowing performance enhancement when resources are available.**
- **Objective**
  - **Provide flexible approach to enable applications to adjust to available system resources.**
- **Status**
  - **University grant project (UIUC)**

PCA 2: Component Technologies for Reliability and Resource Management

Program and Project Milestones

- **Project Milestones Supporting PCA 2**
  - **HPCC 2.2: Develop embedded tools and services for autonomous resource estimation/request of local and distributed ground-based systems (12/02)**
    - Develop mechanisms for adaptive networking capability via application resource management (NR-2.2.2: 09/01)
    - Demonstrate throughput improvement in 3 applications utilizing adaptive networking capability (NR-2.2.4: 12/02)

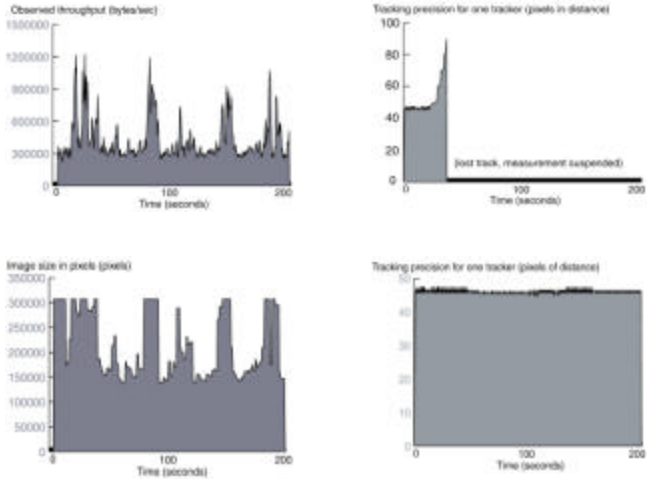
PCA 2: Component Technologies for Reliability and Resource Management

Technology: *Adaptive Middleware*

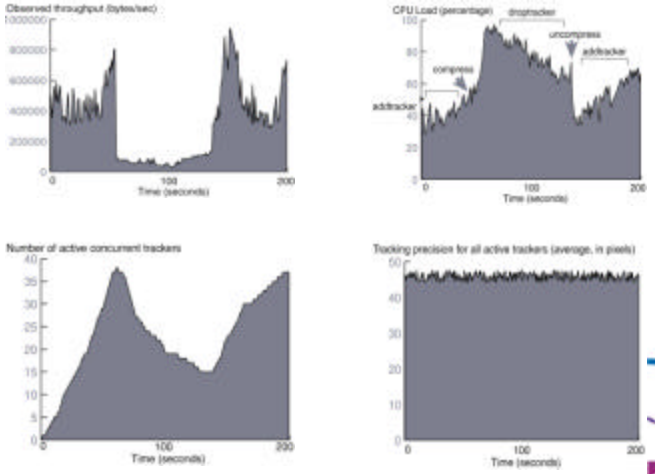
QoS Programming and Development Environment

- Principal Investigator for grant activity: Klara Nahrstedt, University of Illinois, Urbana-Champaign
- Developed middleware for adaptive QoS to enable multimedia application to adapt to availability of system resources and maintain acceptable performance
- Validated middleware approach with Omni-Directional Distributed Visual Tracking Application
- Future focus is development of general middleware framework to support the development of multimedia applications with QoS as an integral part of the application
- NASA multimedia applications that will benefit from this research:
  - Electron Microscopy
  - Remote Aviation Help Desk

Tracking Precision without and with Adaptive Control



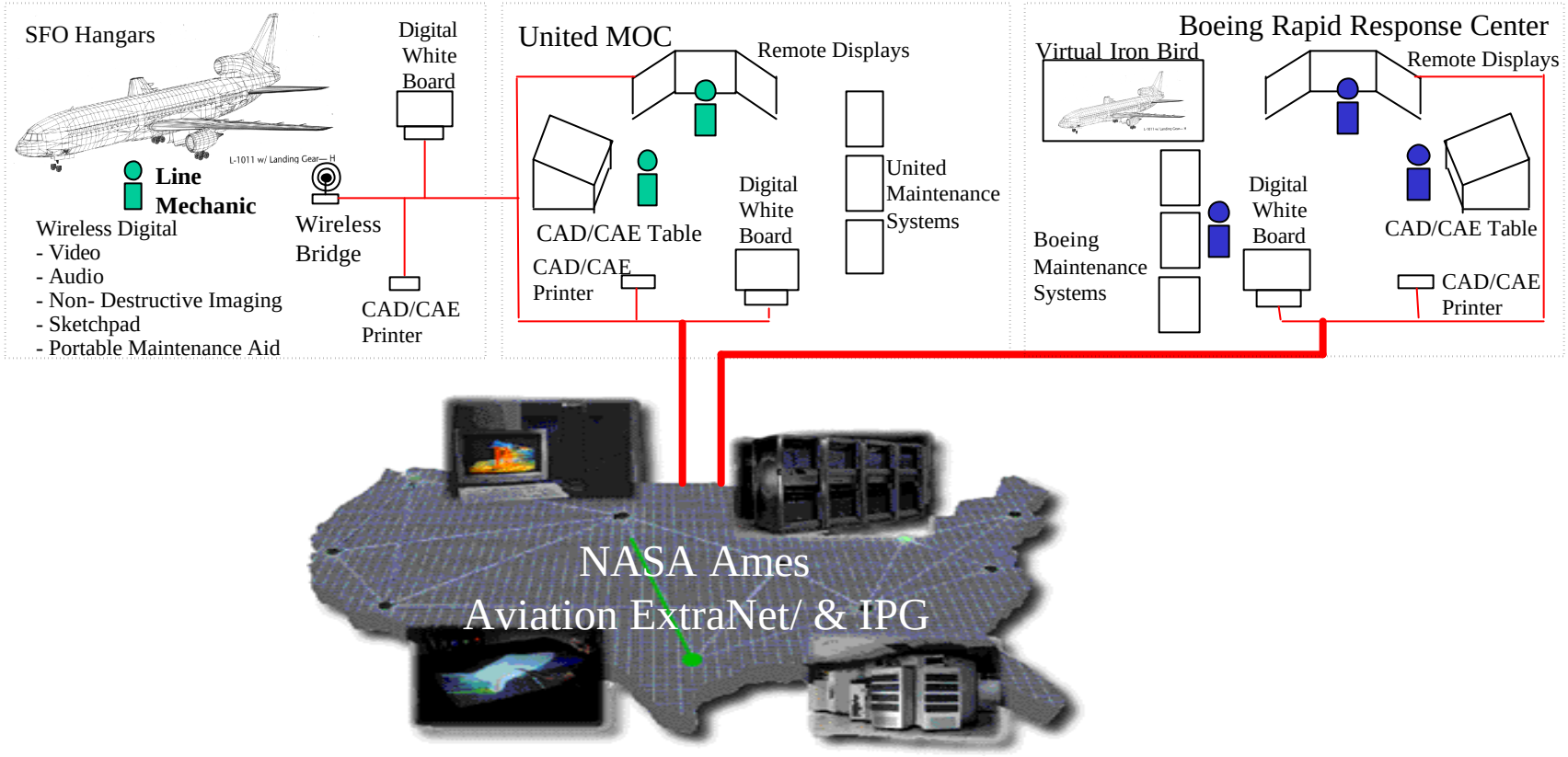
Tracking Precision using Fuzzy Logic Adaptation



PCA 2: Component Technologies for Reliability and Resource Management

Technology: *Adaptive Middleware*

Remote Aviation Help Desk (RAHD)



PCA 2: Component Technologies for Reliability and Resource Management

HPCC NASA

Technology: *Adaptive Middleware*

Remote Aviation Help Desk (RAHD)

- **Project Goal**
  Prototype advanced information technologies to improve aircraft maintenance operations.
- **Challenge**
  - **The RAHD is an extension of the Boeing Rapid Response Center and a convergence of several advanced Information Technology (IT) projects within NASA, Ames Research Center:**
    - Aviation ExtraNet/IsoWAN
    - Portable Maintenance Aid
    - Science Desk
    - Data Sharing Level III
    - Intelligent Vehicle Health Monitoring
- **Partnerships**
  - **NASA Ames, Boeing**
  - **UIUC: NREN grant activity leverages funding from other sources**

PCA 3: Component Technologies for Reliability and Resource Management

HPCC NASA

Program and Project Milestones

		Planned Completion
HPCC	**3.2: Interoperable and portable networking technologies**	**09/02**
NR-3.2.1	Document current NGI network multicast status and provide instruction and guidance on deployment of native multicasting	06/00
NR-3.2.2	Deploy prototype QoS mechanisms in the WAN environment	12/00
NR-3.2.3	Demonstration of native multicast among NGI networks	09/01
NR-3.2.4	Deploy prototype Traffic Engineering mechanisms in WAN environment	03/02
NR-3.2.5	Deploy QoS capabilities within the NGI networks	09/02

PCA 3

NREN

NASA Research & Education Network

Multicast

PCA 3: Component Technologies for Interoperability and Portability

HPCC NASA

Technology: *Multicast*

- **Project Milestones Supporting PCA 3**
  - **HPCC 3.2: Interoperable and portable networking technologies (09/02)**
    - Document current NGI network multicast status and provide instruction and guidance on deployment of native multicasting (NR-3.2.1 06/00)
    - Demonstration of native multicast among NGI networks (NR-3.2.3 09/01)

PCA 3: Component Technologies for Interoperability and Portability

HPCC NASA

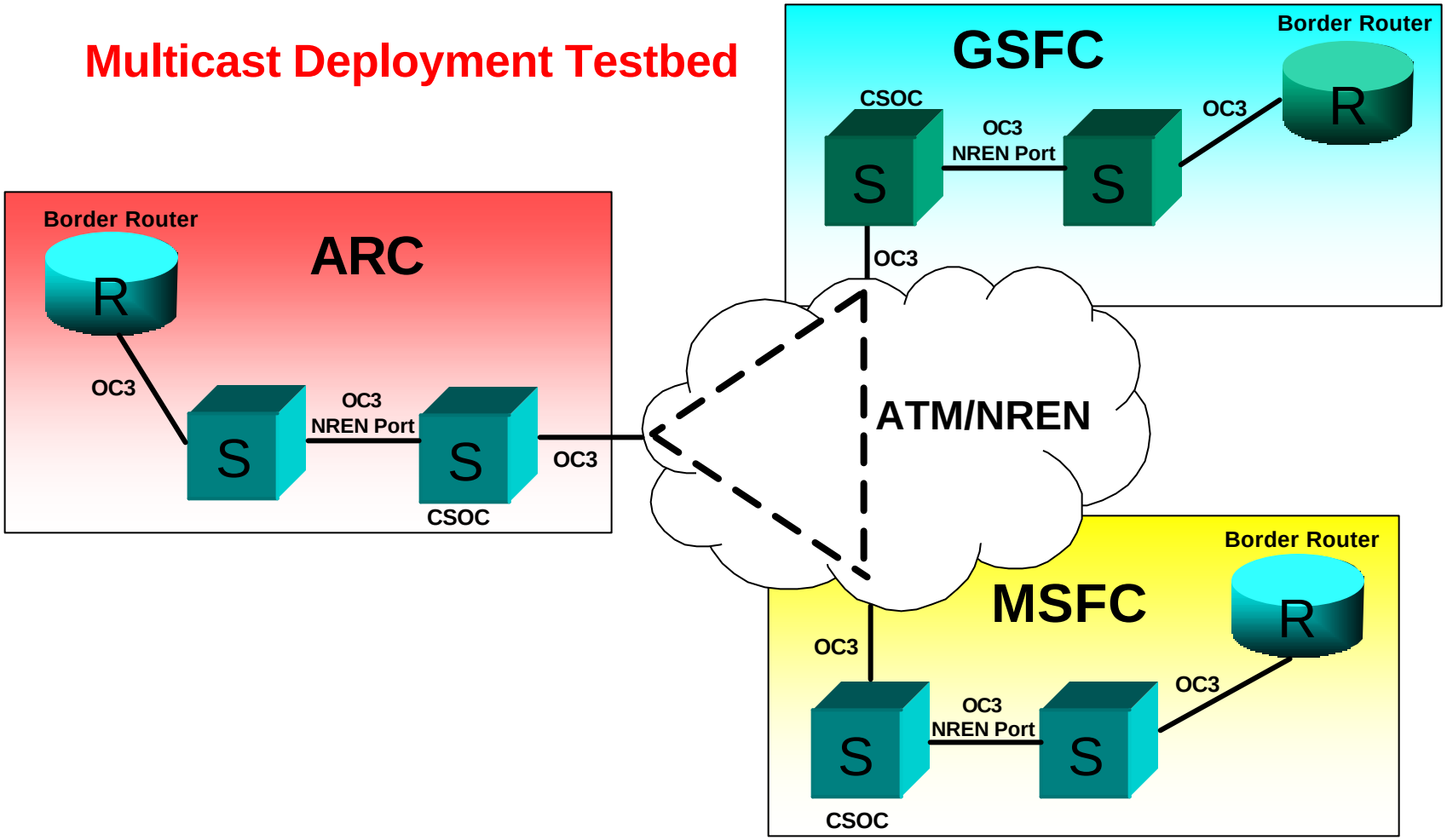
Technology: *Multicast*

- **Implementation Plan**
  - **Native multicast has been demonstrated across all NGI networks except NISN (VCC application - May 1999)**
  - **IP Multicast transition to NISN**
    - IP Multicast Demonstration Plan almost complete
    - Initial deployment of IP multicast will be in testbed lab run by PRISMS (ARC, MSFC, GSFC)
    - NREN providing technical direction and funding
    - Primary challenge: the contract structure for NISN is not designed to adapt to rapid technological change

PCA 3: Component Technologies for Interoperability and Portability

Technology: *Multicast*

Multicast Deployment Testbed



PCA 3

NASA Research & Education Network

NREN

Quality of Service

PCA 3: Component Technologies for Interoperability and Portability

HPCC NASA

Technology: *Quality of Service (QoS)*

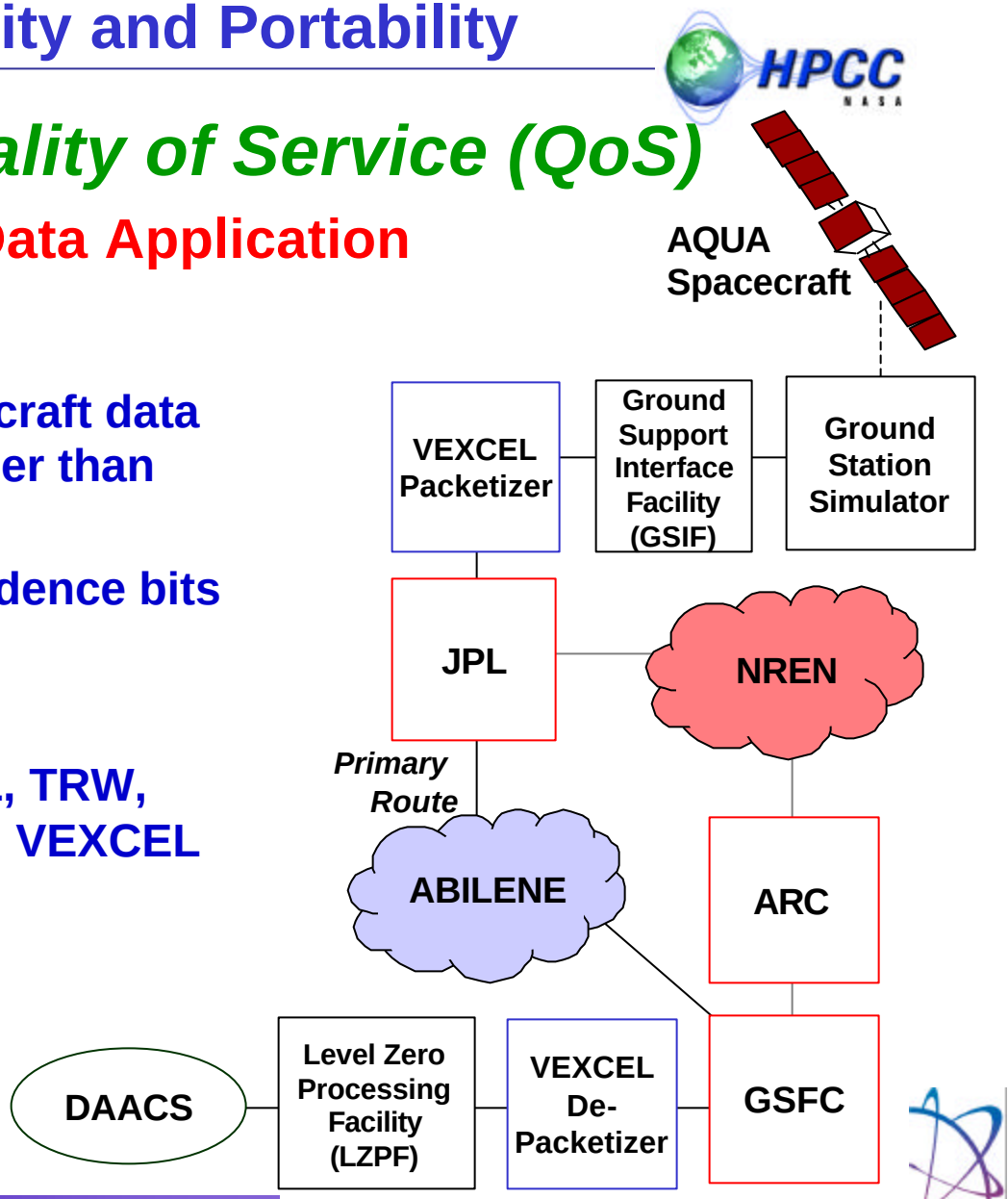
- **Project Milestones Supporting PCA 3**
  - **HPCC 3.2: Interoperable and portable networking technologies (09/02)**
    - Deploy prototype QoS mechanisms in the WAN environment (NR-3.2.2: 12/00)
    - Deploy QoS capabilities within the NGI networks (NR-3.2.5: 09/02)
- **Implementation Plan**
  - **QoS lab testing complete**
    - Queuing mechanisms
    - Traffic shaping
    - Rate limiting
    - IP precedence bits
  - **Qbone activities**
    - Qbone is Internet2 DiffServ Testbed
    - NREN was selected as early Qbone participant
    - Currently deploying Abilene Premium Service on Qbone
- **Partnerships**
  - **ESDIS**

PCA 3: Component Technologies for Interoperability and Portability

Technology: *Quality of Service (QoS)*

Clock and Data Application

- **Goal**
  - Transmit Level Zero spacecraft data over shared networks, rather than leased lines
  - Investigate use of IP precedence bits to prioritize traffic
- **Partners**
  - NASA Goddard, NASA JPL, TRW, Abilene, CalREN2, ATDnet, VEXCEL



PCA 3

NASA Research & Education Network

NREN

Traffic Engineering

PCA 3: Component Technologies for Interoperability and Portability

HPCC NASA

Technology: *Traffic Engineering*

- **Definition**
  - Traffic engineering capabilities include assigning traffic to specific network routes providing rapid traffic adaptation to changes in network topology and incorporating administrative policies in the routing process.
- **Objective**
  - Enhance network performance by distributing traffic evenly across network resources.
- **Status**
  - All network traffic in the Internet is currently routed the same.

PCA 3: Component Technologies for Interoperability and Portability

HPCC NASA

Technology: *Traffic Engineering*

- **Project Milestones Supporting PCA 3**
  - **HPCC 3.2: Interoperable and portable networking technologies (09/02)**
    - Deploy prototype traffic engineering mechanisms in WAN environment (NR-3.2.4: 03/02)

PCA 5: Integrated HPCC Technologies

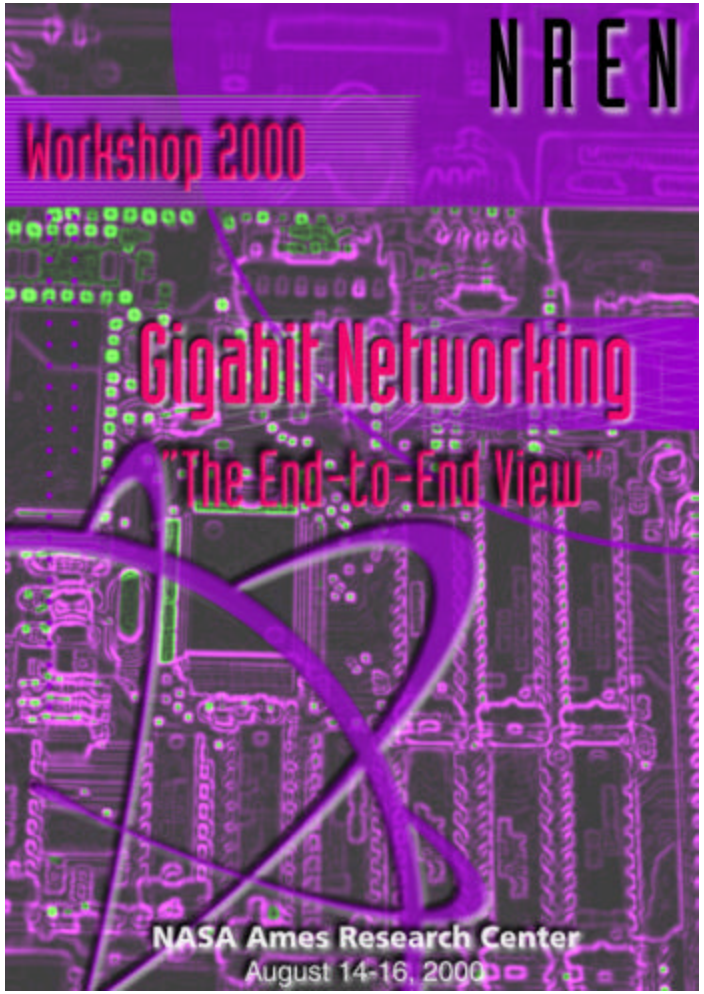
Program and Project Milestones

		Planned Completion
PCA 5.6: Demonstrate end-to-end networking capabilities on NASA mission-oriented applications		**09/02**
NR-5.6.1	Demonstrate advanced networking techniques for relevant mission applications utilizing high-speed networking	09/00
NR-5.6.2	Demonstrate advanced networking techniques for relevant mission applications utilizing gigabit WAN capability	03/01
NR-5.6.3	Demonstrate advanced networking techniques for relevant mission applications utilizing QoS tools	09/01
NR-5.6.4	Performance testing confirming end-to-end gigabit capability	09/01
NR-5.6.5	Demonstrate advanced hybrid networking techniques for relevant mission applications	03/02
NR-5.6.6	Demonstrate application-embedded traffic engineering techniques	09/02

PCA 5: Integrated HPCC Technologies

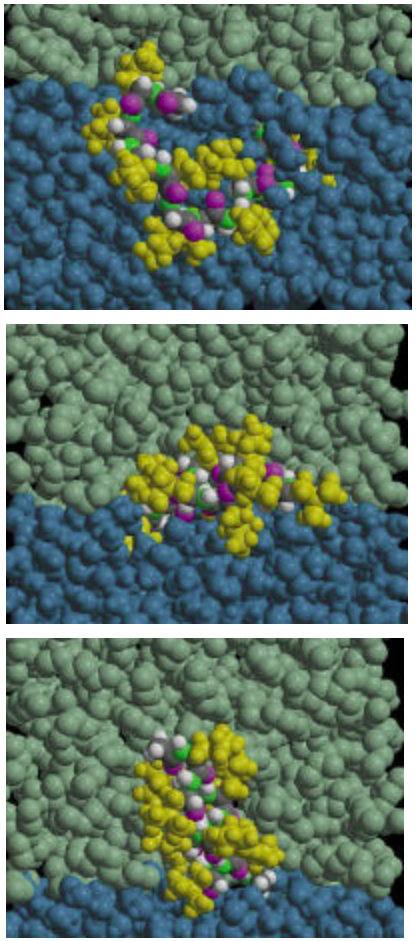
NREN Workshop

- Gigabit Networking: The End-to-End View
- Hosted by NREN, August 2000
- Objective
  - Provide forum for sharing perspectives, reaching consensus, and coordinating gigabit networking activities among multiple Federal Agencies and university groups
  - Develop application roadmaps for demonstrating true end-to-end gigabit/second networking by the end of 2002



PCA 5: Integrated HPCC Technologies

Astrobiology—Molecular Modeling Application

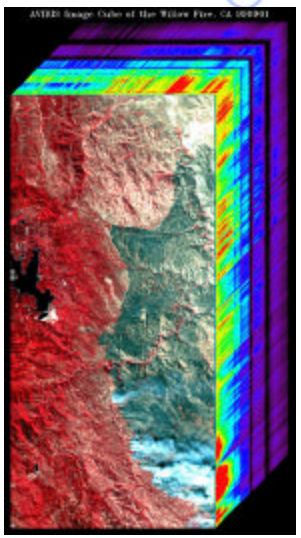


- **Goal**
  - To demonstrate realtime visualization and manipulation of data-intensive simulations in computational Astrobiology.
- **Challenge**
  - Provide high-quality service for simulations.
  - Speeds of 500 to 600 Mbps are expected.
- **Partners**
  - NASA Ames, NASA JPL, Harvard, San Diego Supercomputing Center

PCA 5: Integrated HPCC Technologies

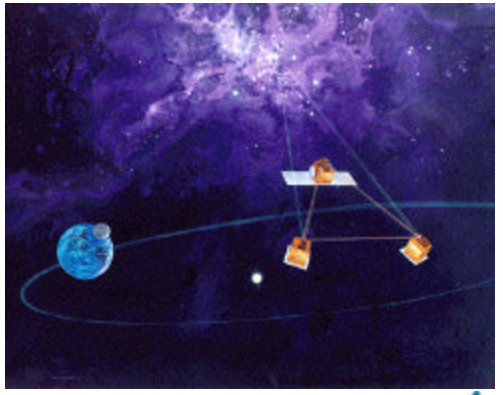
Digital Earth/Sky Application

- **Project Goal**
  - The NASA Earth and Space Science Enterprise goal is “human telepresence” throughout the Earth and solar systems.
- **Challenge**
  - Requires high performance remote access and visualization for very large Earth and space data sets in the U.S. and worldwide.
- **Partners**
  - NASA Goddard, NASA JPL



Willow fire in Southern California's San Bernardino County

New Millennium Interferometer



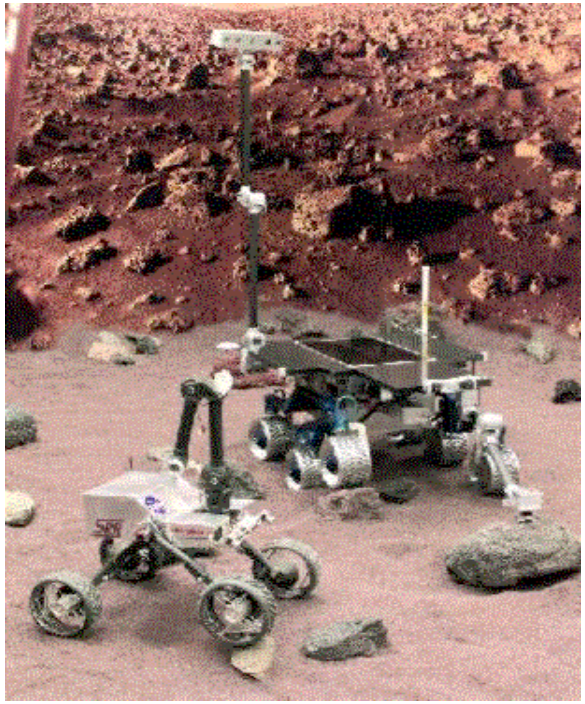
PCA 5: Integrated HPCC Technologies

Mars Rover Application

- **Goal**

  Create a unified terrain and visualization environment between ARC and JPL and simulate Mars robotic exploration scenarios.

  The Ames Autonomy and Robotics Area has an ongoing research program developing machine vision and 3D visualization methods to support science robot operations. This project delivers 3D terrain models and visualization tools to the Mars Pathfinder operations and science teams.



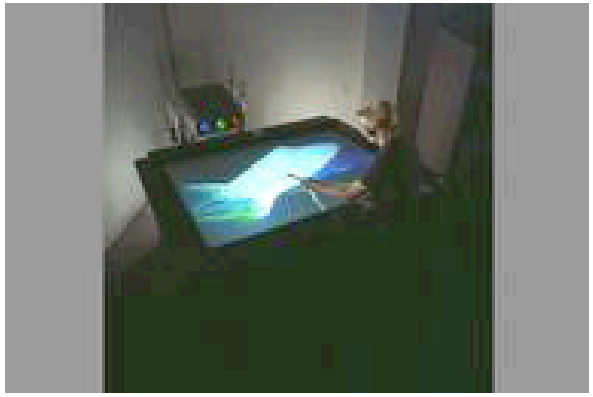
- **Challenge**
  - **Guarantee latency.**
  - **Guarantee video quality.**
  - **Provide a high-speed, determinable bandwidth connection between ARC and JPL required for transmission of large data sets for visualization and modeling.**
  - **During field tests, visualize 3D images in Ames Future Flight Central.**
- **Partners**
  - **NASA Ames, NASA JPL**

PCA 5: Integrated HPCC Technologies

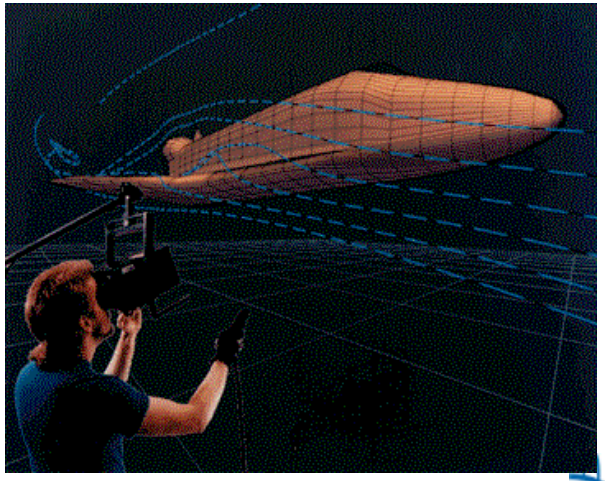
Virtual Wind Tunnel Application

- **Goal**

  The virtual wind tunnel supports a variety of visualization techniques. Most of these techniques are designed so that a researcher can move the visualizations about, exploring phenomena in a desired region of space.



- **Challenge**
  - The NASA Ames Virtual Wind Tunnel is an environment for the analysis of 3-D computer-simulated flow fields.
  - The Virtual Wind Tunnel is part of an integrated design system that encompasses computer tools, data bases, laboratories, plants, and people.
  - NREN would provide high-performance networking (high reliability, low latency, etc.) to connect numerous private, public and academic research laboratories, computers and scientists into a worldwide system with immense design powers.



- **Partners**
  - NASA Ames, NASA Langley, NASA JPL

PCA 6: Significant Engineering, Scientific and Educational Impacts

Program and Project Milestones

		Planned Completion
HPCC 6.1: Establish impact on Earth and Space Sciences through the demonstration of a production-ready high-performance Earth and Space Science computational simulation validated by NASA Enterprise observational mission data		**09/03**
NR-6.1.1	Demonstrate gigabit technologies for Earth and Space Sciences	09/02
NR-6.1.2	Demonstrate QoS capability for Earth and Space Sciences	06/03
NR-6.1.3	Demonstrate integrated QoS and gigabit technologies for Earth and Space Sciences	09/03
HPCC 6.3: Establish impact on aerospace design and operations through demonstration of integrated systems of applications, tools, services and resources which enable the high-performance execution of interoperable aerospace applications across distributed heterogeneous testbeds		**09/05**
NR-6.3.1	Demonstrate gigabit technologies for aerospace design	09/03
NR-6.3.2	Demonstrate QoS capability across multiple network domains for Aerospace	09/04
NR-6.3.3	Demonstrate adaptive middleware technologies for Aerospace	09/05

PCA 6: Significant Engineering, Scientific and Educational Impacts

Program and Project Milestones (Cont.)

		Planned Completion
HPCC 6.4: Establish impact of NASA's education mission through demonstration of prototype revolutionary multisensory multimedia systems for education		**09/05**
NR-6.4.1	Demonstrate tools to optimize network performance	09/04
NR-6.4.2	Demonstrate performance enhancements achieved by utilizing integrated adaptive middleware technologies	09/05

PCA 7: Sustainable and Widespread Customer use of HPCC Program Technologies

Program and Project Milestones

		Planned Completion
HPCC WAN	**7.5: Transfer NREN technologies to NASA's operational**	**09/06**
NR-7.5.1	Deploy native multicast protocols	09/01
NR-7.5.2	Deploy gigabit networking technologies across LANs and WANs	09/02
NR-7.5.3	Deploy QoS technologies	09/03
NR-7.5.4	Deploy hybrid networking technologies	09/04
NR-7.5.5	Deploy adaptive middleware technologies	09/05
NR-7.5.6	Deploy traffic engineering technologies	09/06

PCA 7: Sustainable and Widespread Customer use of HPCC Program Technologies

Status

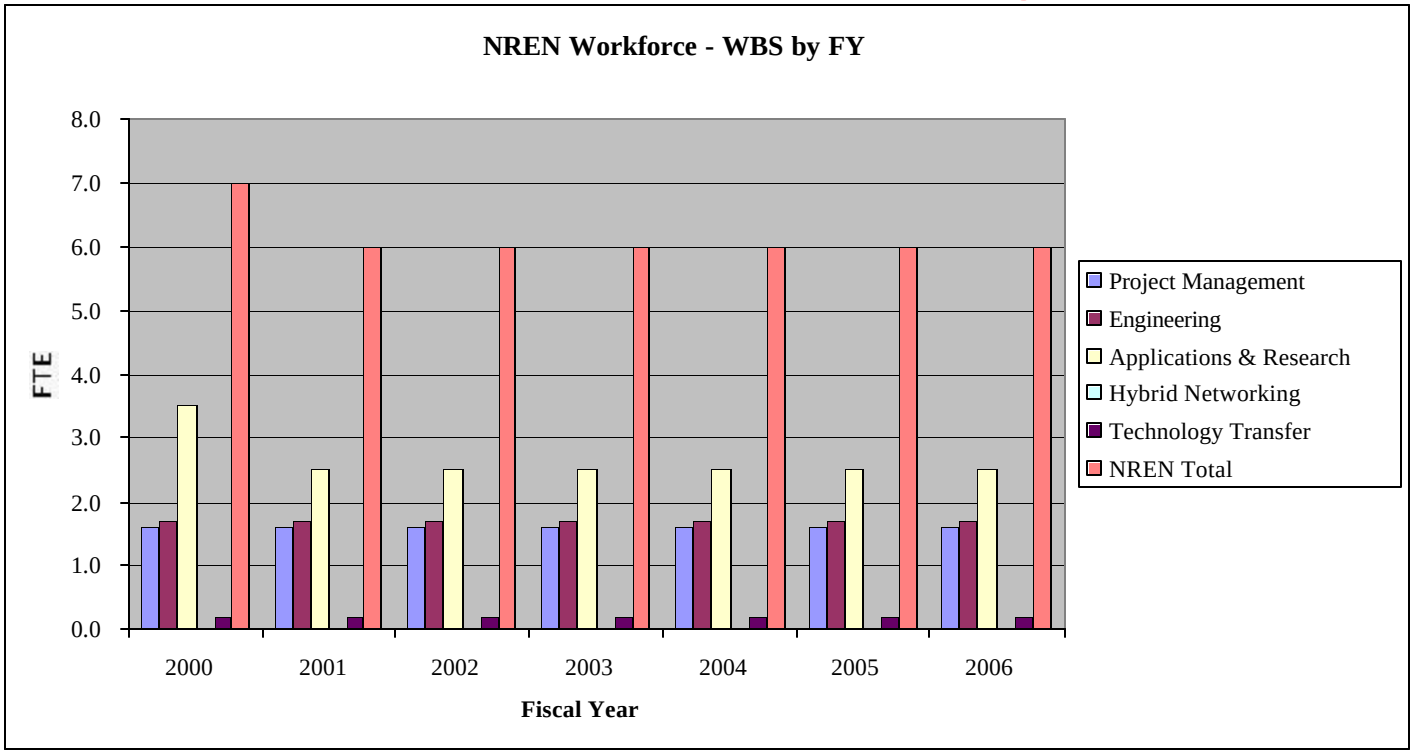
- **Project Milestones Supporting PCA 7**
  - **HPCC 7.5: Transfer NREN technologies to NASA's operational WAN (9/06)**
    - Deploy native multicast protocols (NR-7.5.1: 09/01)
    - Deploy QoS technologies (NR-7.5.3: 09/03)
    - Deploy hybrid networking technologies (NR-7.5.4: 09/04)
- **Multicast**
  - **NISN Advanced Technology team currently prototyping technology**
  - **Cisco provided simulation of NISN PIP network within their lab**
  - **Two customers scheduled for operational services by 11/00 (Virtual Motion Simulator, ISS)**
  - **Cost analysis for business model in progress**
- **QoS**
  - **NISN evaluating current progress benefiting the Mission network upgrade to IP environment**
- **Hybrid Network**
  - **SOMO technology team collaborating with NREN to provide operation solutions for ISS deployment**

Resources

Civil Servant Workforce

Project Structure

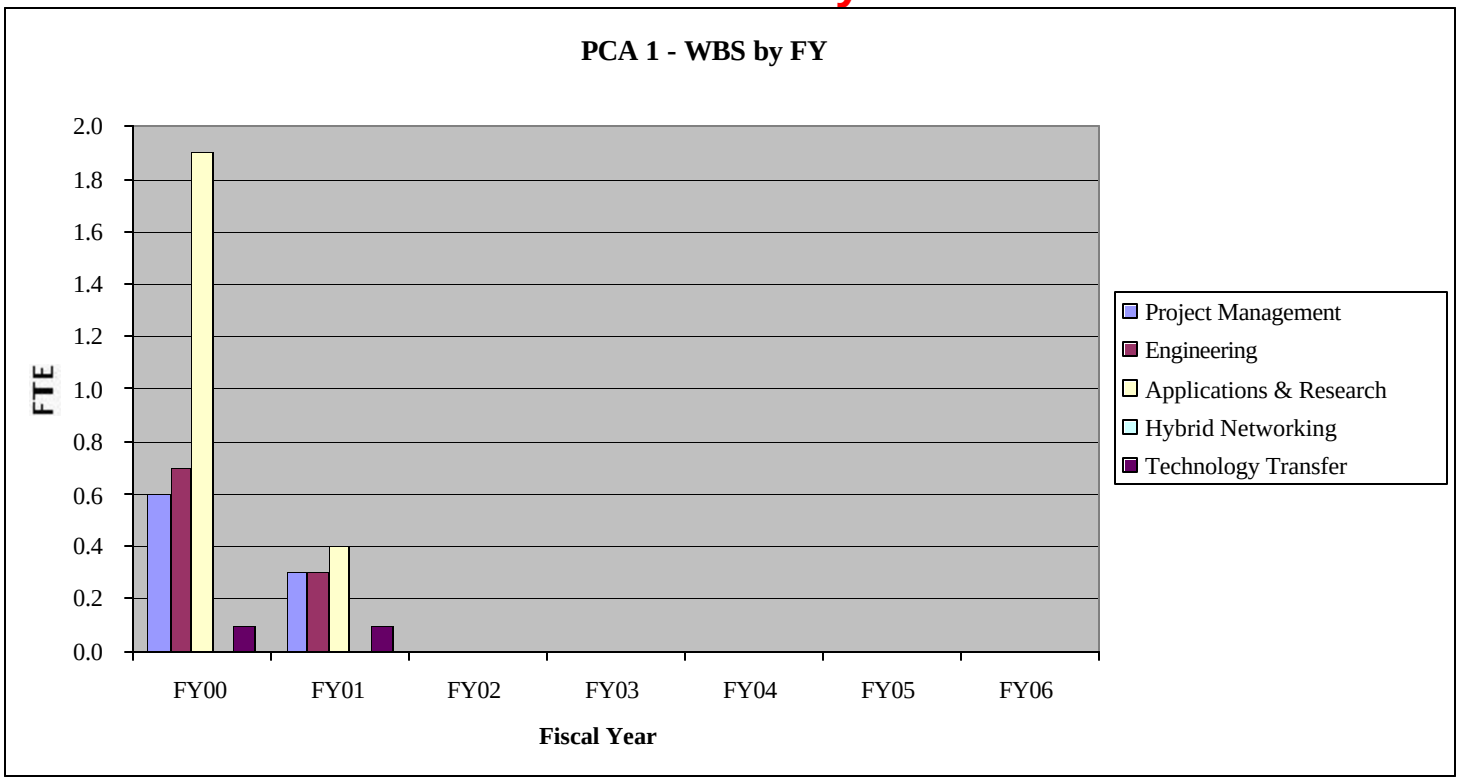
Civil Servant Workforce by WBS



	2000	2001	2002	2003	2004	2005	2006
Project Management	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Engineering	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Applications & Research	3.5	2.5	2.5	2.5	2.5	2.5	2.5
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NREN Total	**7.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**

PCA 1: Component Technologies for Performance

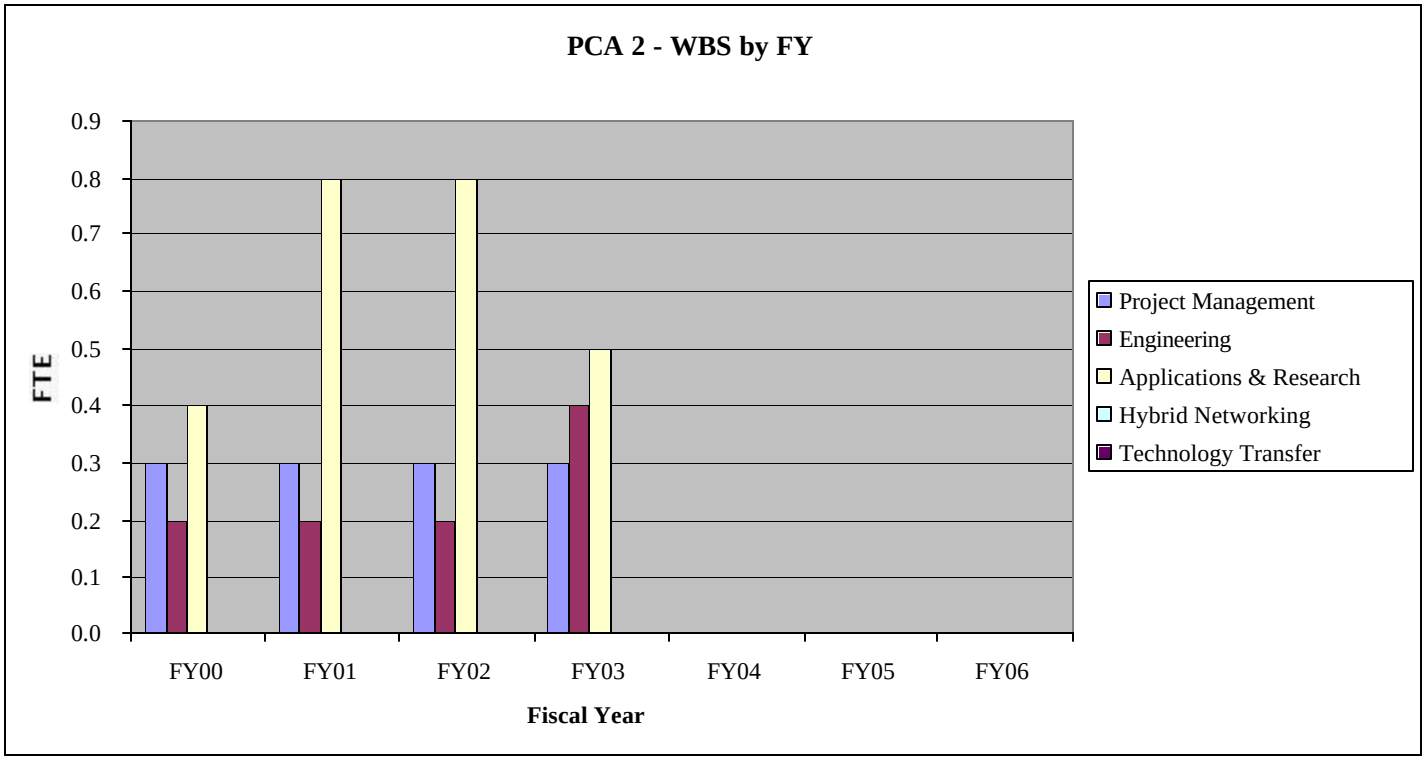
Civil Servant Workforce by WBS for PCA 1



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.6	0.3	0.0	0.0	0.0	0.0	0.0
Engineering	0.7	0.3	0.0	0.0	0.0	0.0	0.0
Applications & Research	1.9	0.4	0.0	0.0	0.0	0.0	0.0
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.1	0.1	0.0	0.0	0.0	0.0	0.0

PCA 2: Component Technologies for Reliability and Resource Management

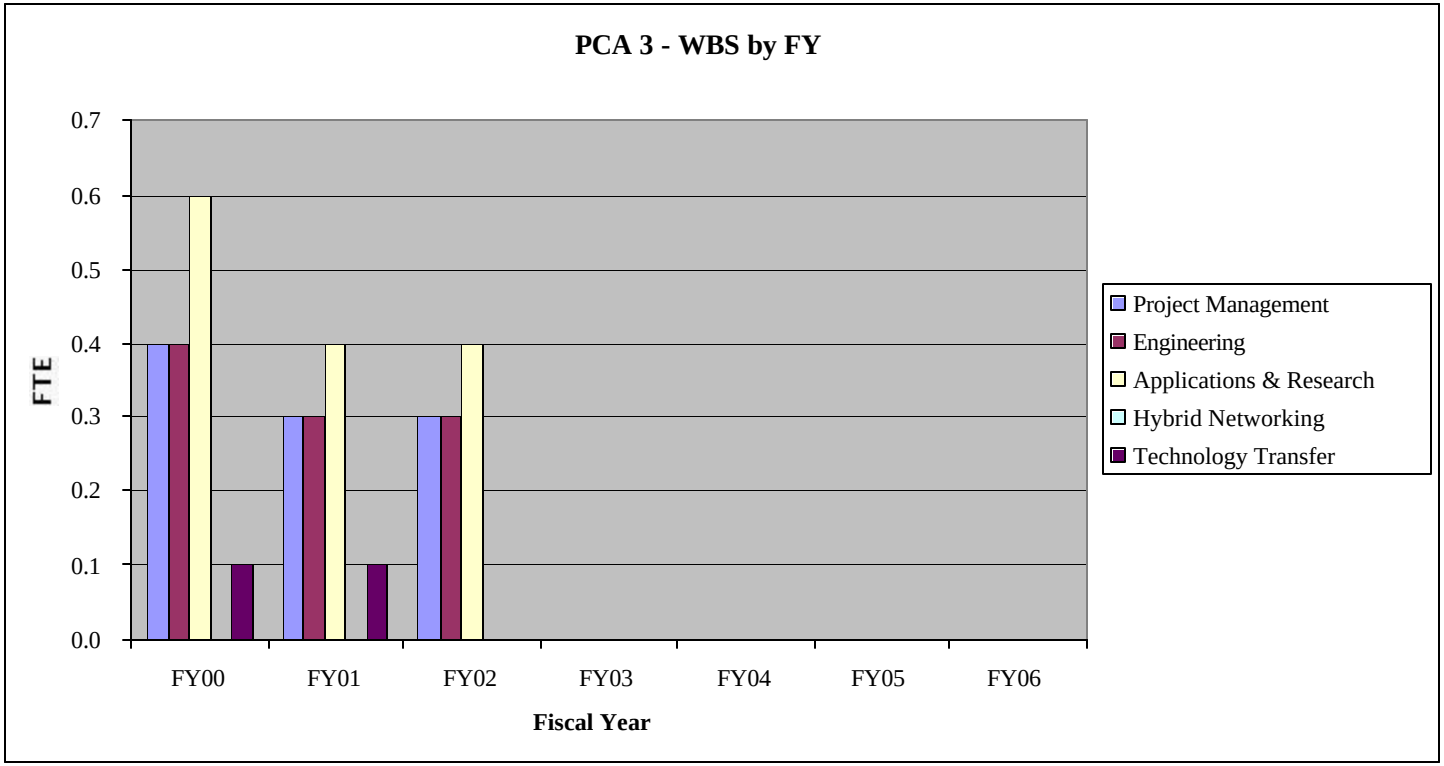
Civil Servant Workforce by WBS for PCA 2



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Engineering	0.2	0.2	0.2	0.4	0.0	0.0	0.0
Applications & Research	0.4	0.8	0.8	0.5	0.0	0.0	0.0
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PCA 3: Component Technologies for Interoperability and Portability

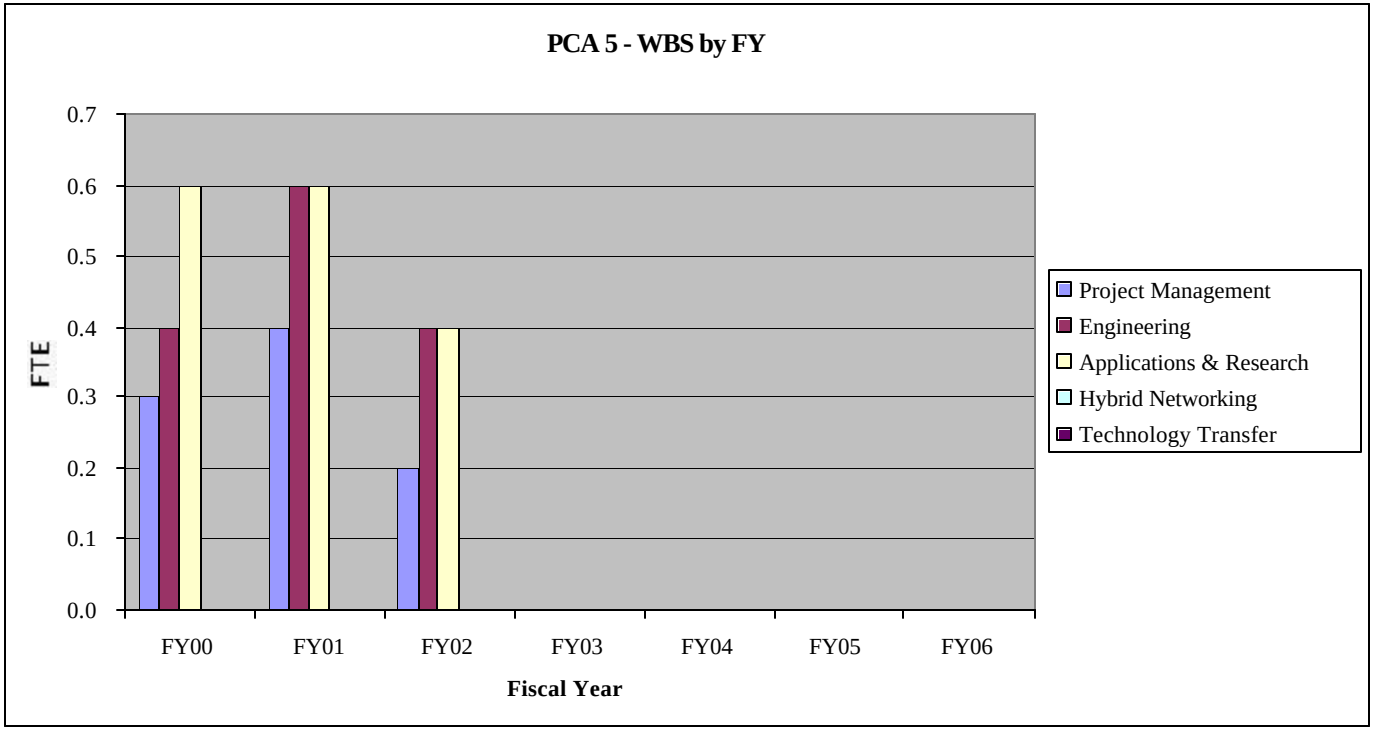
Civil Servant Workforce by WBS for PCA 3



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.4	0.3	0.3	0.0	0.0	0.0	0.0
Engineering	0.4	0.3	0.3	0.0	0.0	0.0	0.0
Applications & Research	0.6	0.4	0.4	0.0	0.0	0.0	0.0
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.1	0.1	0.0	0.0	0.0	0.0	0.0

PCA 5: Integrated HPCC Technologies

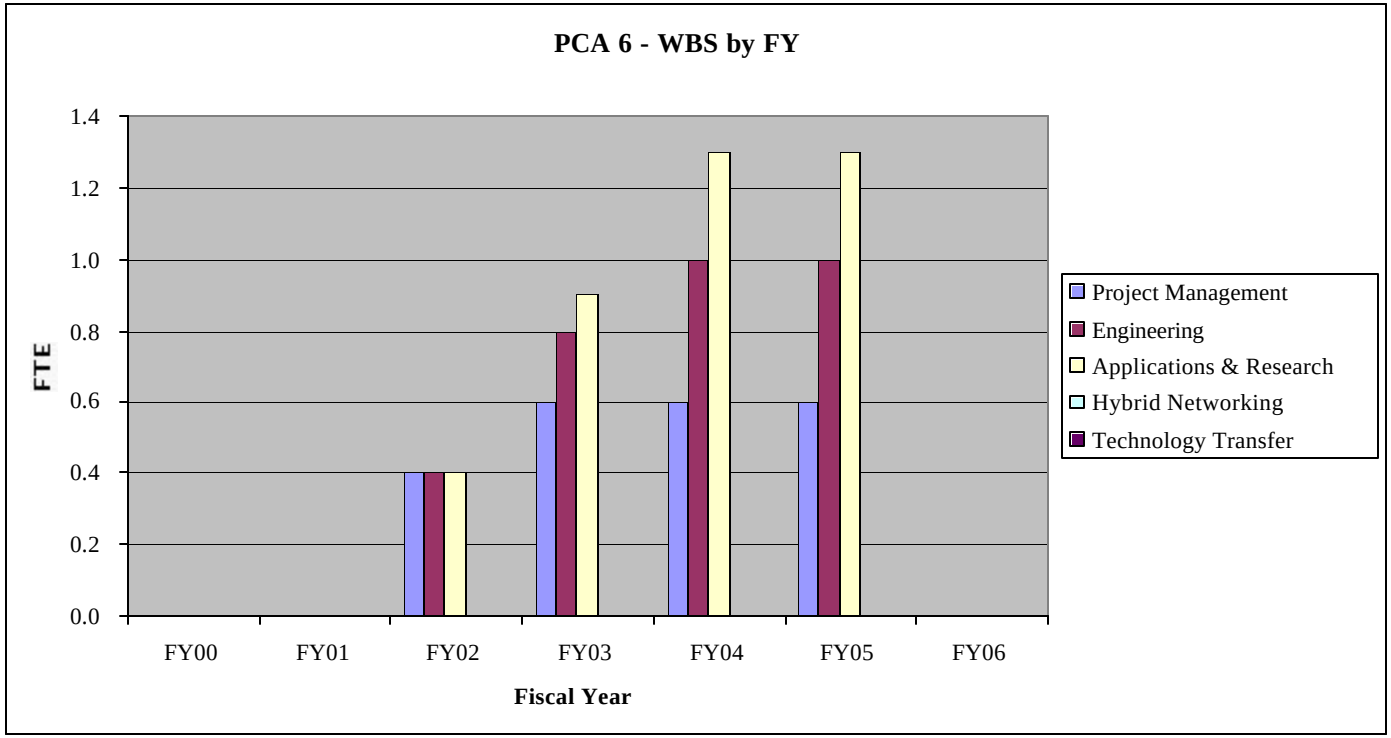
Civil Servant Workforce by WBS for PCA 5



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.3	0.4	0.2	0.0	0.0	0.0	0.0
Engineering	0.4	0.6	0.4	0.0	0.0	0.0	0.0
Applications & Research	0.6	0.6	0.4	0.0	0.0	0.0	0.0
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PCA 6: Significant Engineering, Scientific and Educational Impacts

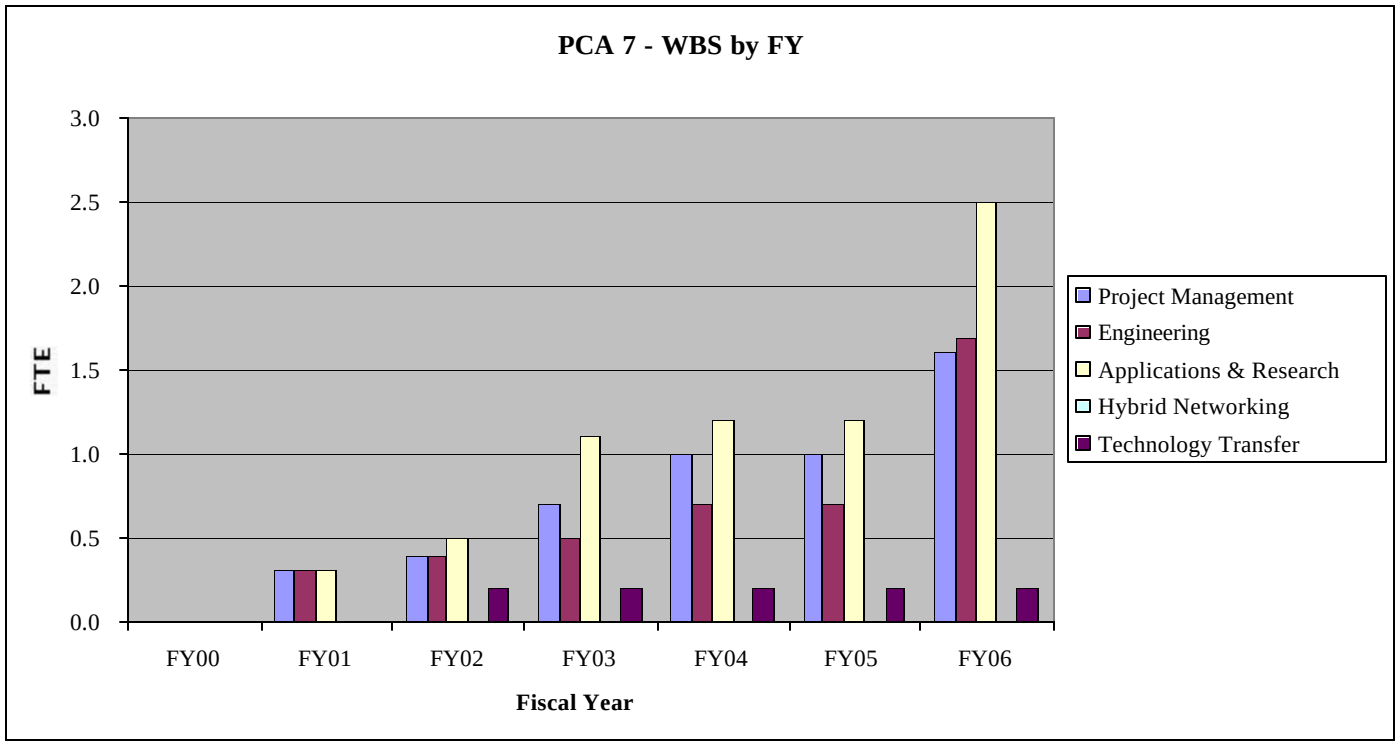
Civil Servant Workforce by WBS for PCA 6



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.0	0.0	0.4	0.6	0.6	0.6	0.0
Engineering	0.0	0.0	0.4	0.8	1.0	1.0	0.0
Applications & Research	0.0	0.0	0.4	0.9	1.3	1.3	0.0
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.0	0.0	0.0	0.0	0.0	0.0	0.0

PCA 7: Sustainable and Widespread Customer use of HPCC Program Technologies

Civil Servant Workforce by WBS for PCA 7



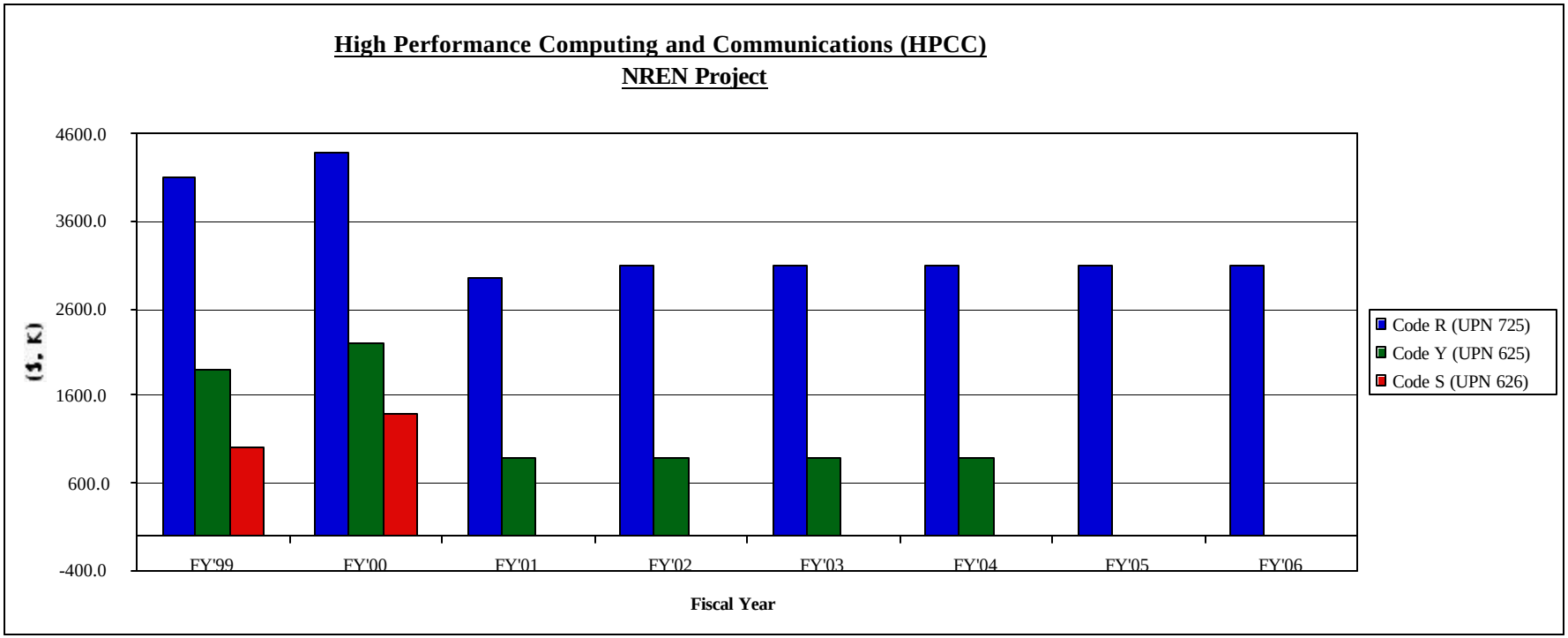
	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0.0	0.3	0.4	0.7	1.0	1.0	1.6
Engineering	0.0	0.3	0.4	0.5	0.7	0.7	1.7
Applications & Research	0.0	0.3	0.5	1.1	1.2	1.2	2.5
Hybrid Networking	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Transfer	0.0	0.0	0.2	0.2	0.2	0.2	0.2

Resources

Budget

Project Structure

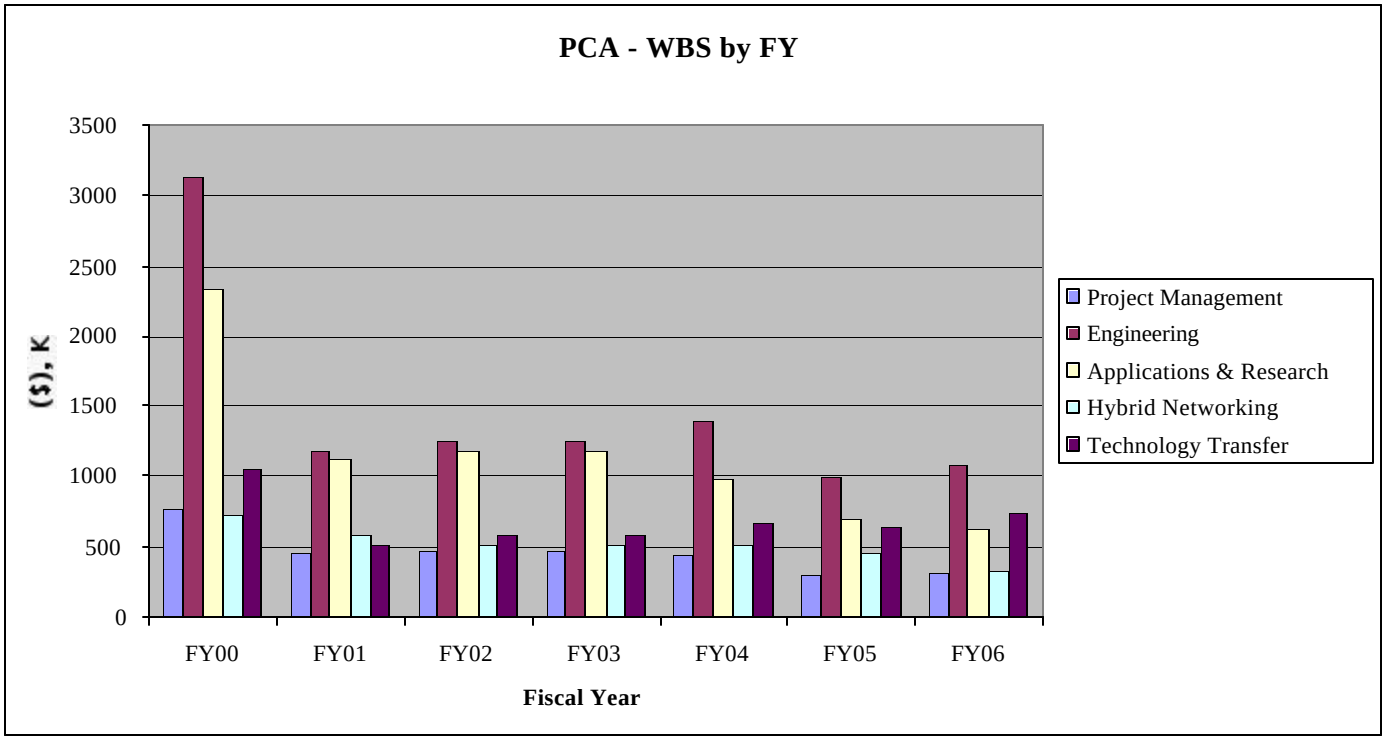
Budget Profile



Funding by Code	CY-1 FY'99	CY FY'00	CY+1 FY'01	CY+2 FY'02	CY+3 FY'03	CY+4 FY'04	CY+5 FY'05	CY+6 FY'06
Code R (UPN 725)	4100.0	4400.0	2950.0	3100.0	3100.0	3100.0	3100.0	3100.0
Code Y (UPN 625)	1900.0	2200.0	900.0	900.0	900.0	900.0		
Code S (UPN 626)	1000.0	1400.0						
Total	7000.0	8000.0	3850.0	4000.0	4000.0	4000.0	3100.0	3100.0

Project Structure

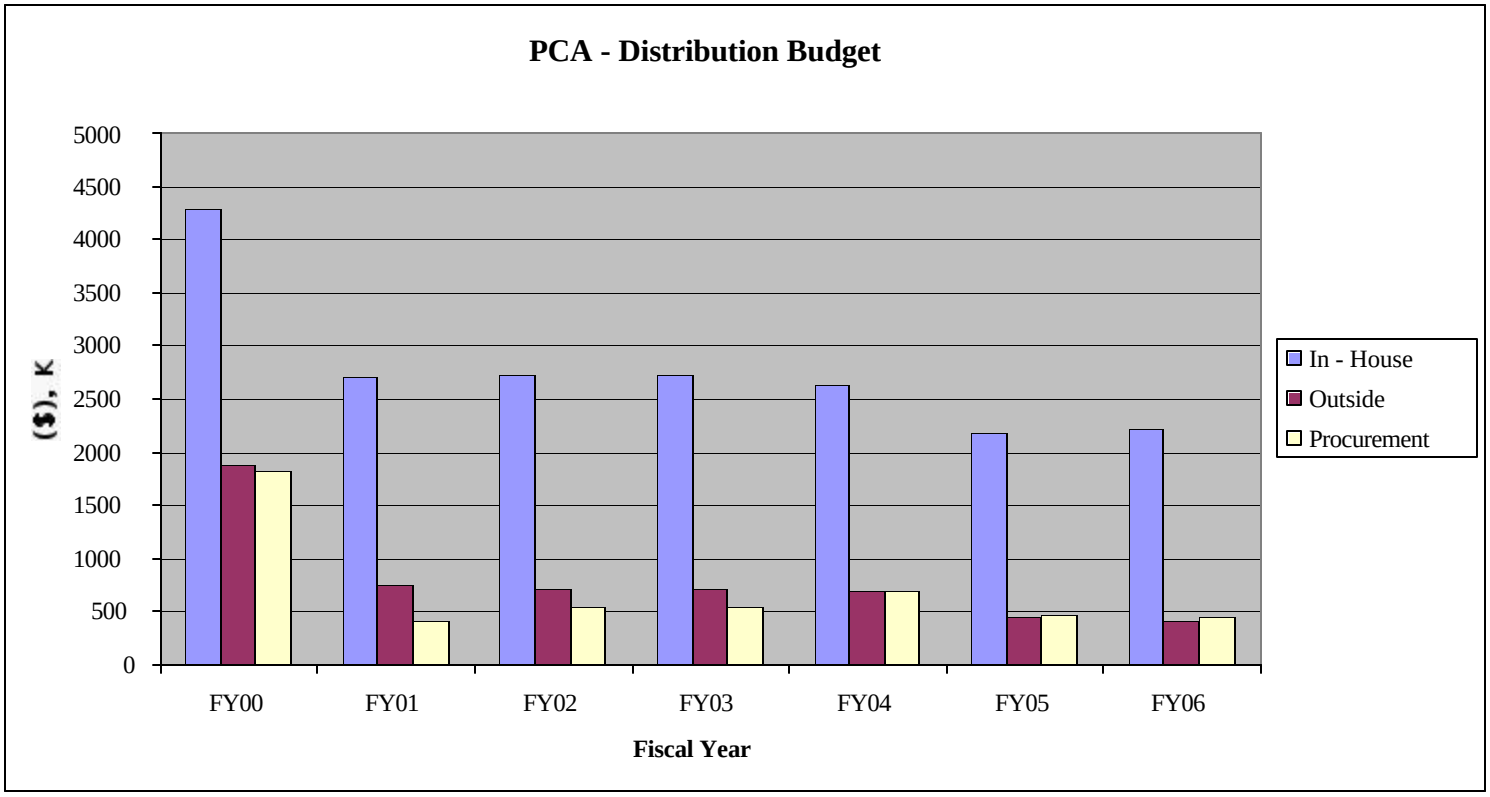
Budget Profile by WBS



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	773	451	462	462	446	304	311
Engineering	3122	1185	1258	1258	1389	990	1091
Applications & Research	2329	1129	1186	1186	978	702	619
Hybrid Networking	725	580	511	511	506	452	331
Technology Transfer	1051	505	583	583	681	652	748

Project Structure

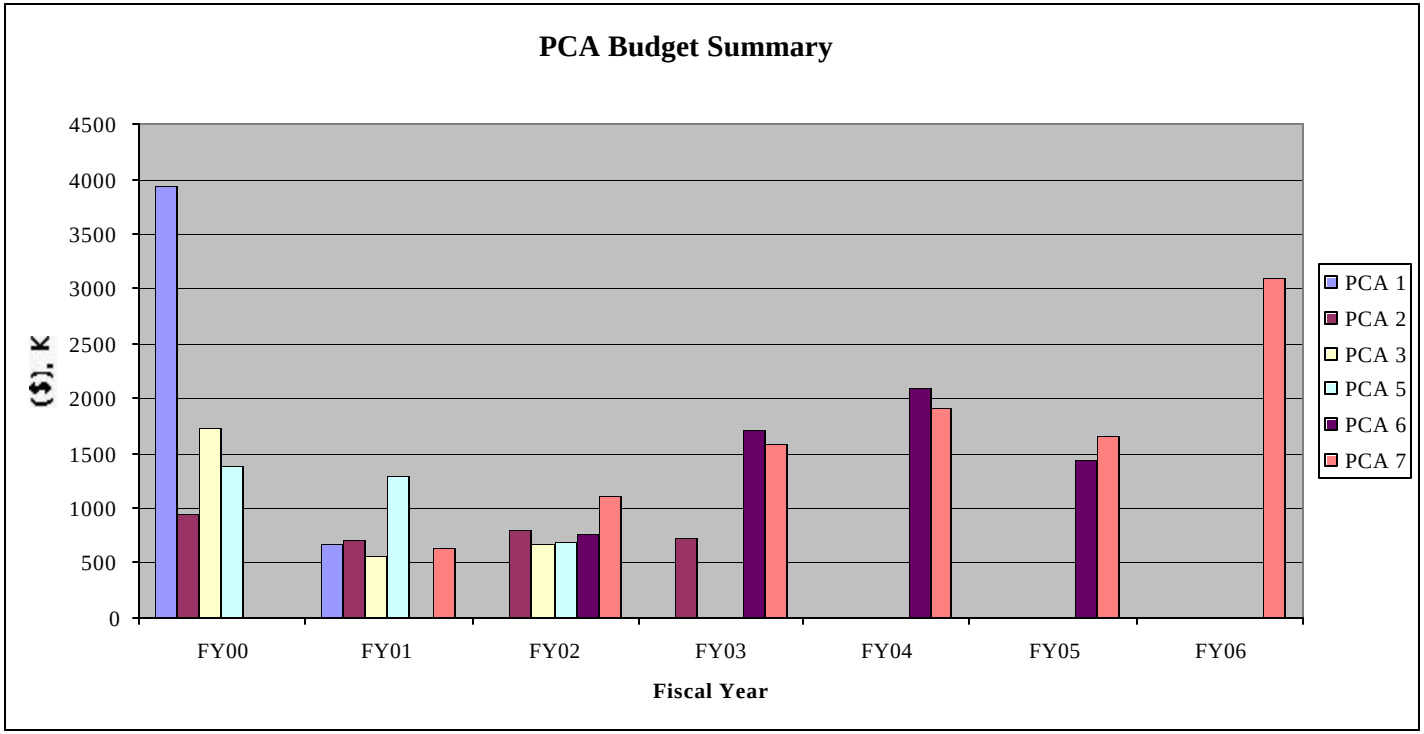
Budget Profile by Distribution



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	4295	2708	2736	2736	2635	2179	2235
Outside	1884	740	709	709	683	458	417
Procurement	1822	401	556	556	681	462	448

Project Structure

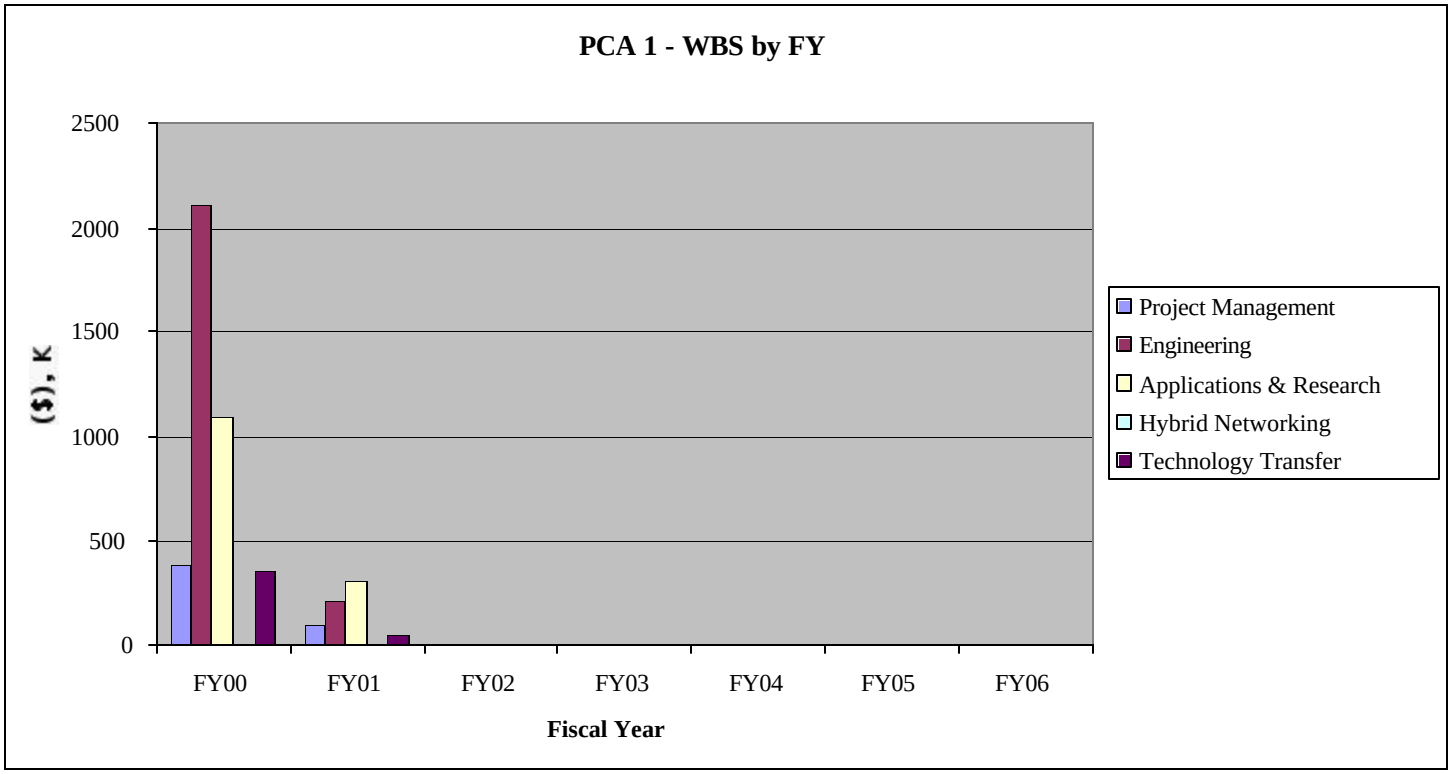
Budget Profile by PCA



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
PCA 1	3943	669	0	0	0	0	0
PCA 2	957	702	785	713	0	0	0
PCA 3	1721	565	660	0	0	0	0
PCA 5	1379	1292	690	0	0	0	0
PCA 6	0	0	757	1708	2090	1449	0
PCA 7	0	622	1108	1579	1910	1651	3100

PCA 1: Component Technologies for Performance

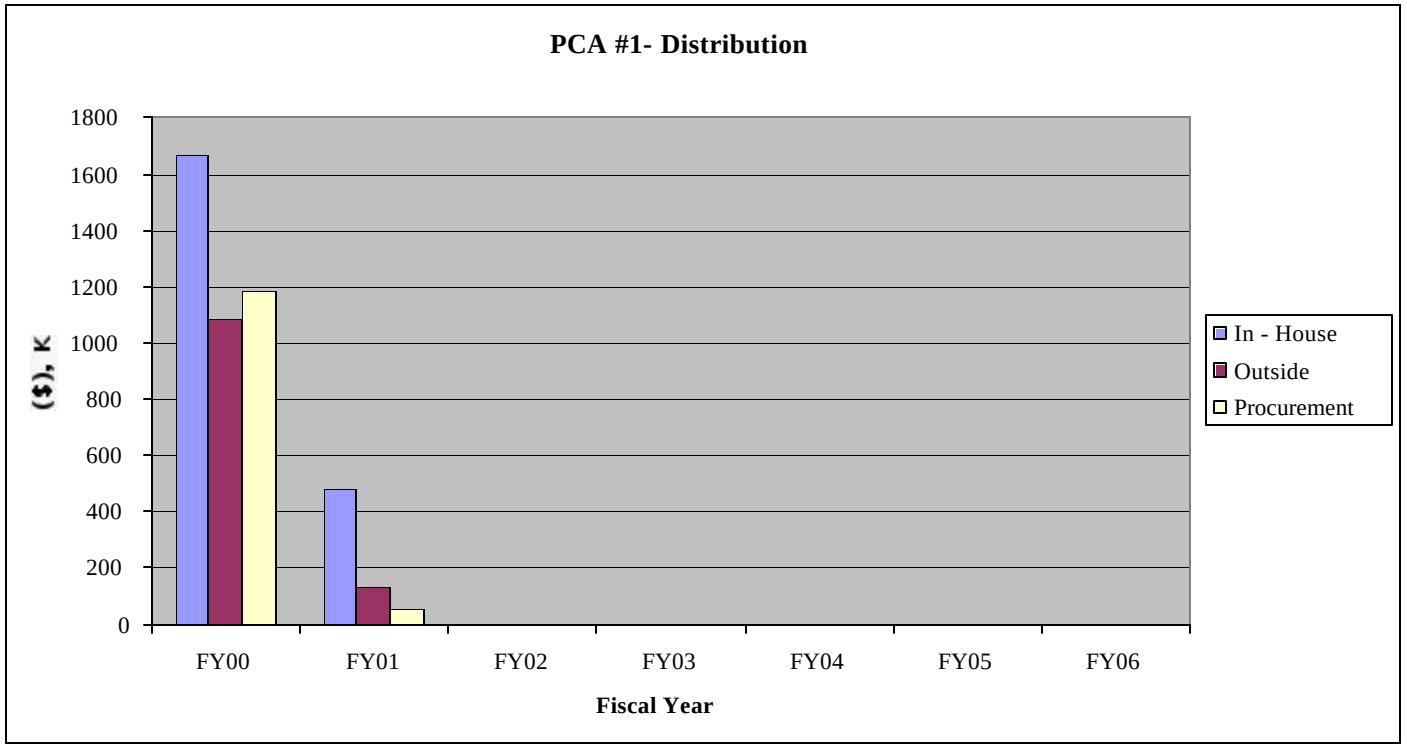
Budget Profile by WBS for PCA 1



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	385	99	0	0	0	0	0
Engineering	2103	213	0	0	0	0	0
Applications & Research	1093	311	0	0	0	0	0
Hybrid Networking	0	0	0	0	0	0	0
Technology Transfer	362	46	0	0	0	0	0

PCA 1: Component Technologies for Performance

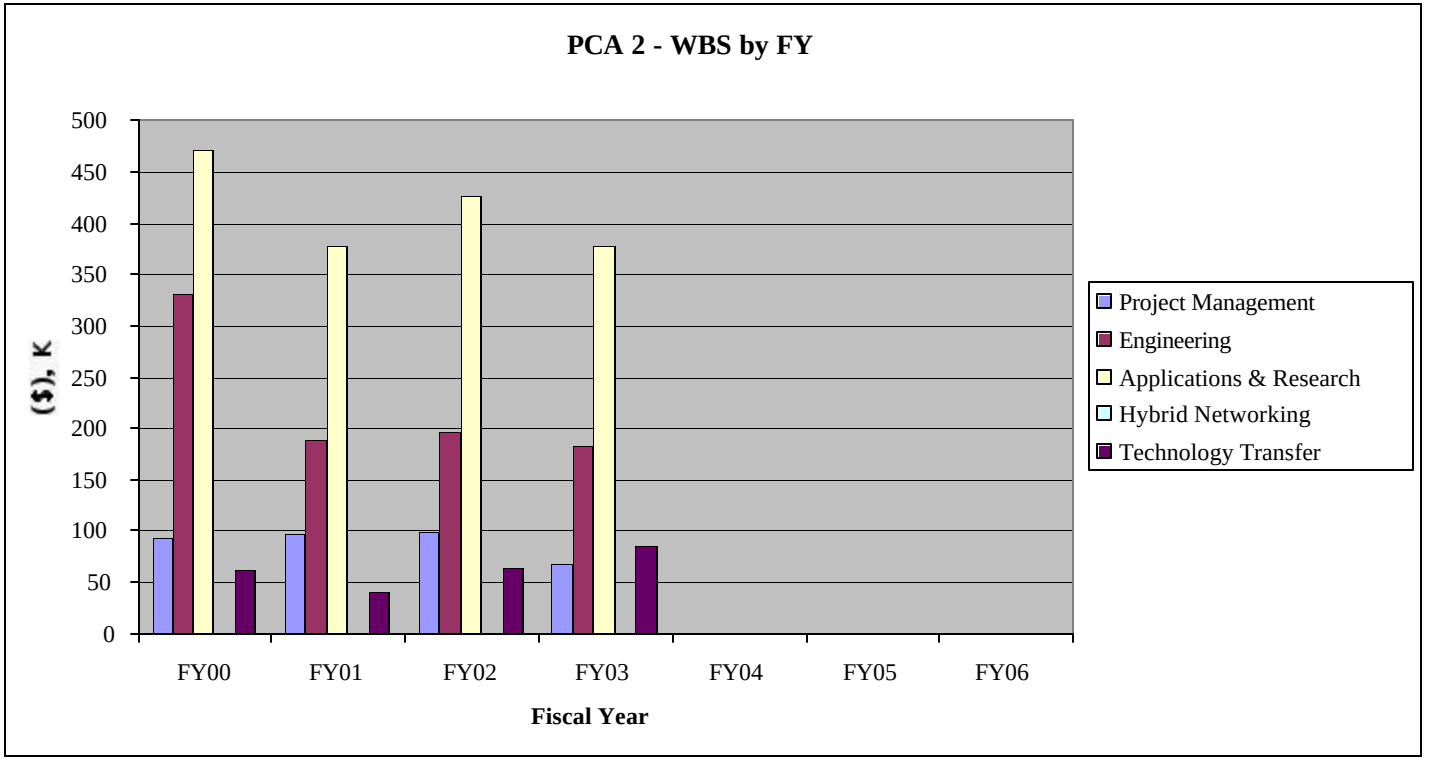
Budget Profile by Distribution for PCA 1



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	1668	483	0	0	0	0	0
Outside	1090	131	0	0	0	0	0
Procurement	1185	55	0	0	0	0	0

PCA 2: Component Technologies for Reliability and Resource Management

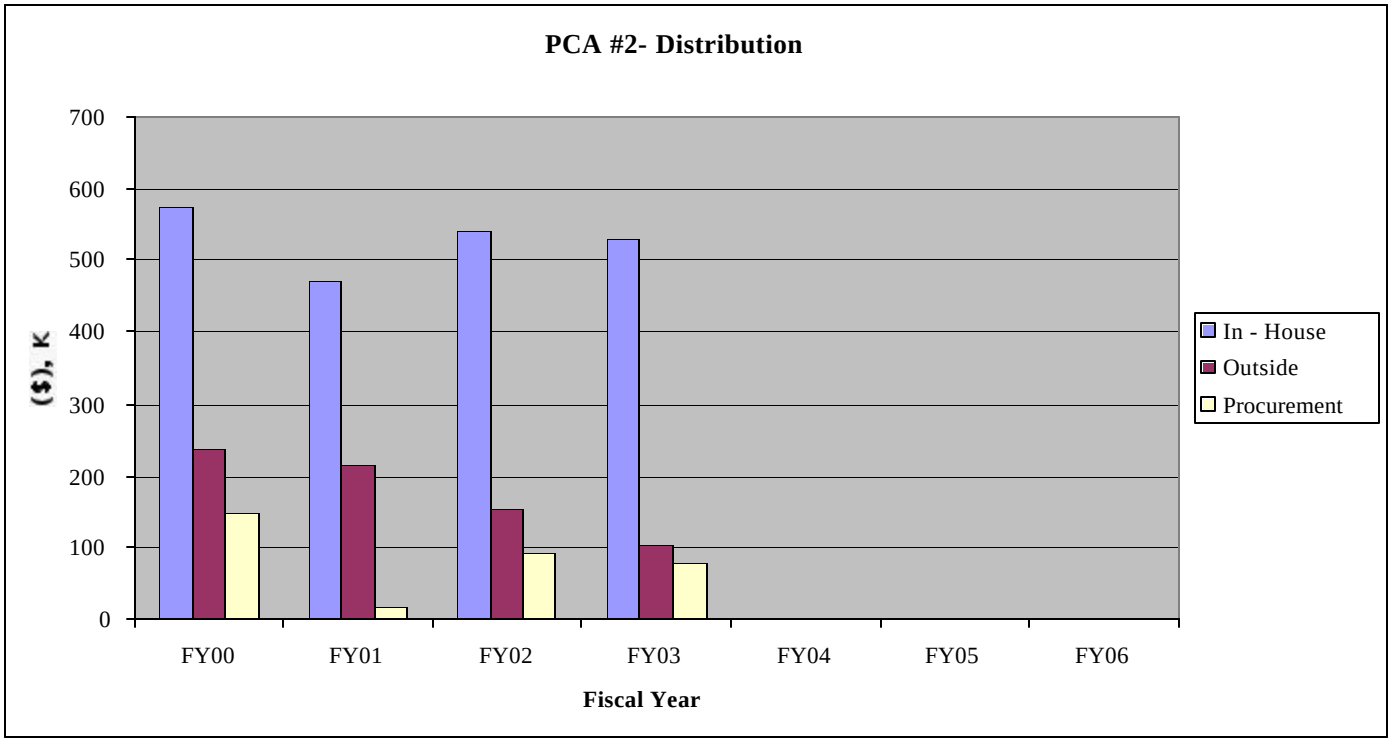
Budget Profile by WBS for PCA 2



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	93	97	99	67	0	0	0
Engineering	332	188	195	183	0	0	0
Applications & Research	470	377	427	377	0	0	0
Hybrid Networking	0	0	0	0	0	0	0
Technology Transfer	62	40	64	86	0	0	0

PCA 2: Component Technologies for Reliability and Resource Management

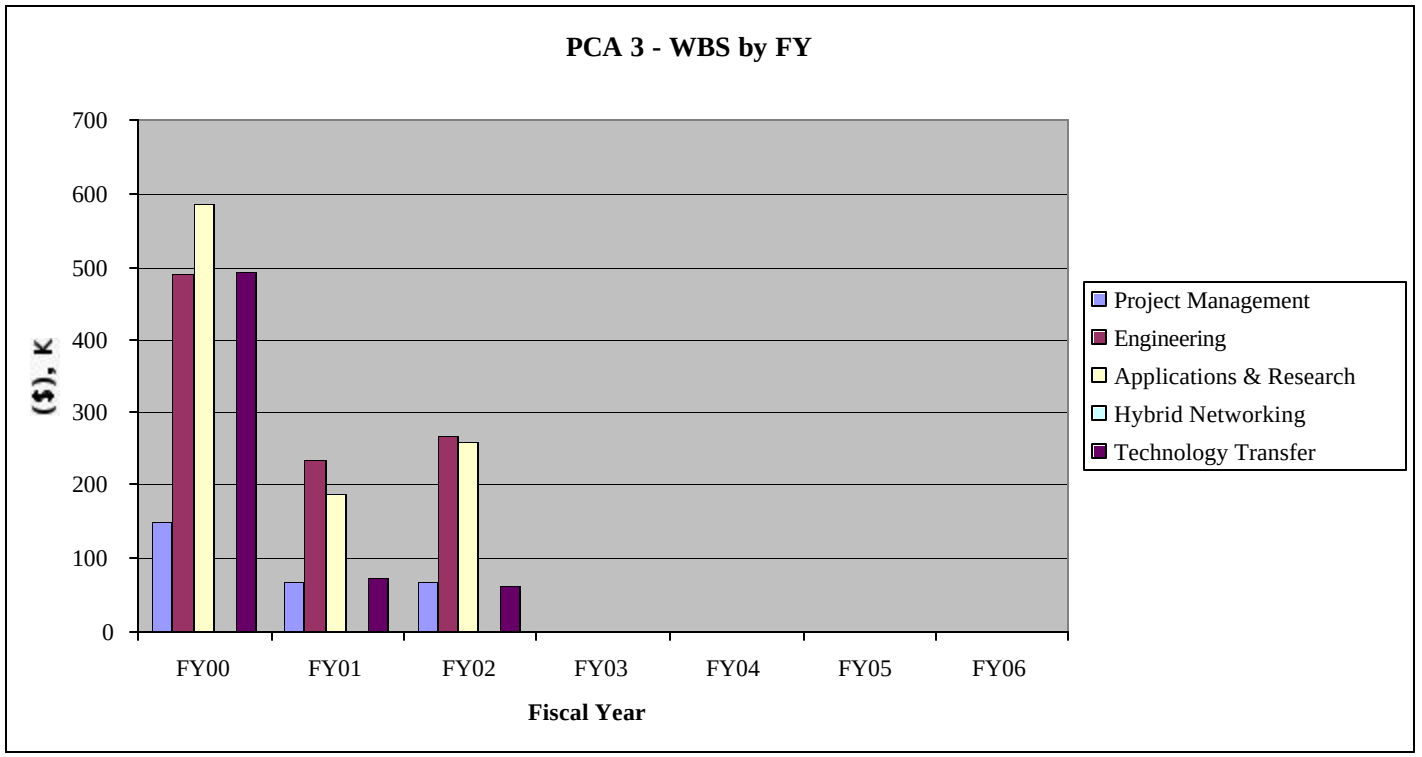
Budget Profile by Distribution for PCA 2



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	574	471	541	531	0	0	0
Outside	236	215	153	105	0	0	0
Procurement	147	15	91	77	0	0	0

PCA 3: Component Technologies for Interoperability and Portability

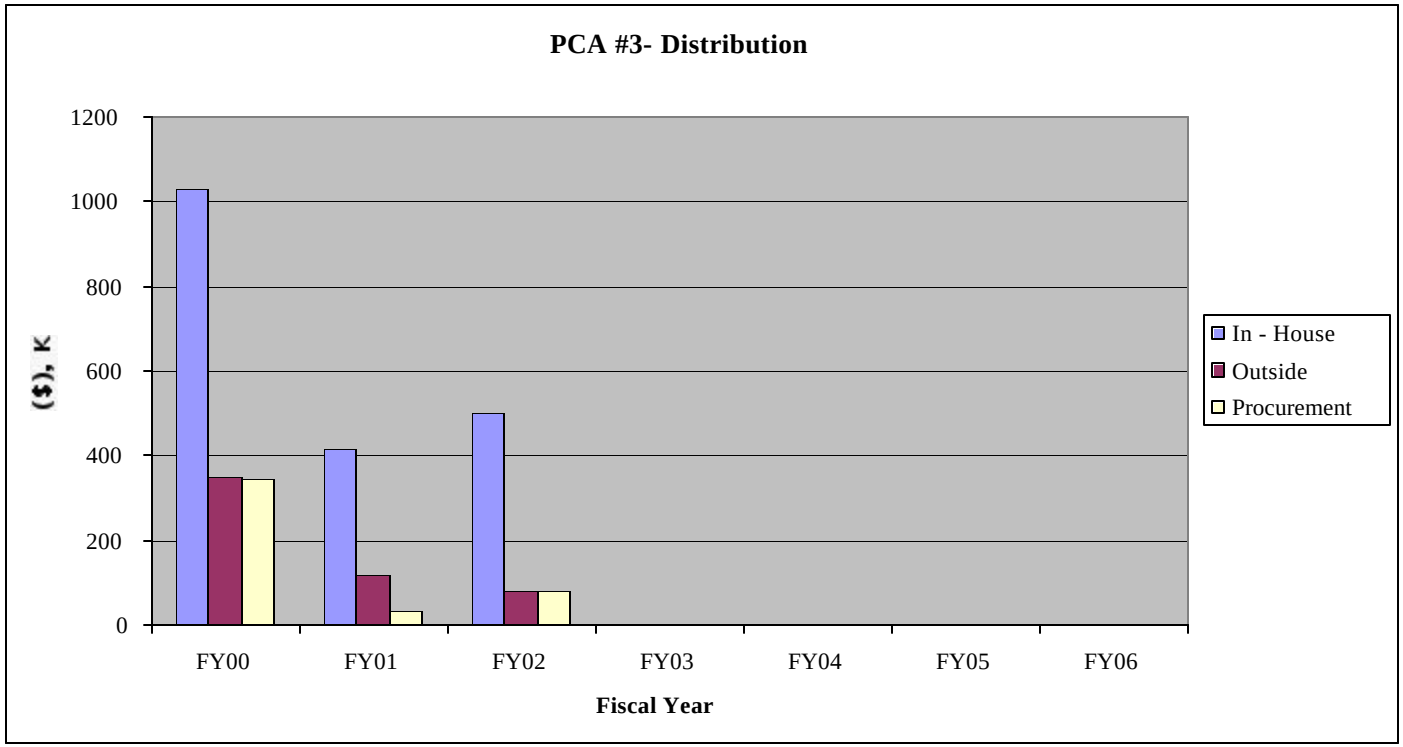
Budget Profile by WBS for PCA 3



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	149	68	69	0	0	0	0
Engineering	491	235	268	0	0	0	0
Applications & Research	586	188	260	0	0	0	0
Hybrid Networking	0	0	0	0	0	0	0
Technology Transfer	495	74	63	0	0	0	0

PCA 3: Component Technologies for Interoperability and Portability

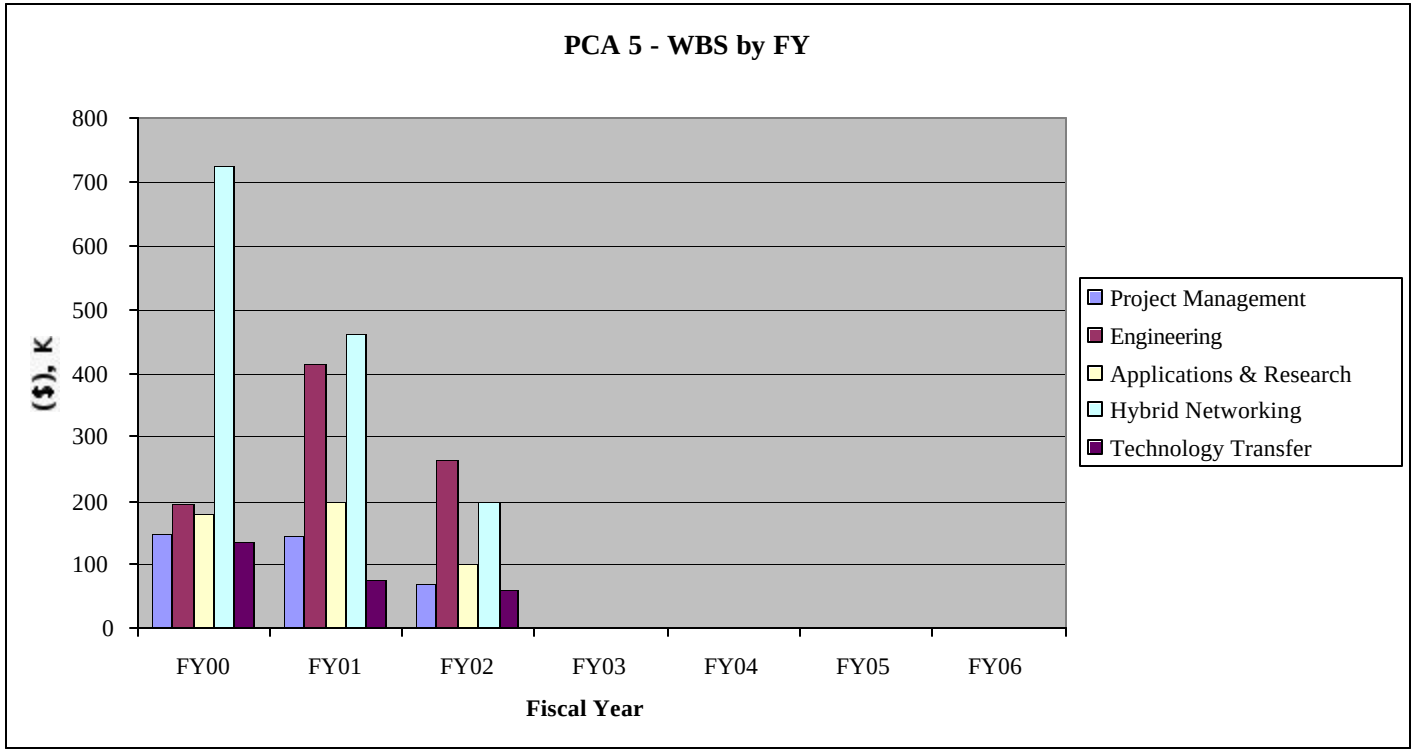
Budget Profile by Distribution for PCA 3



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	1028	417	504	0	0	0	0
Outside	349	115	79	0	0	0	0
Procurement	344	33	77	0	0	0	0

PCA 5: Integrated HPCC Technologies

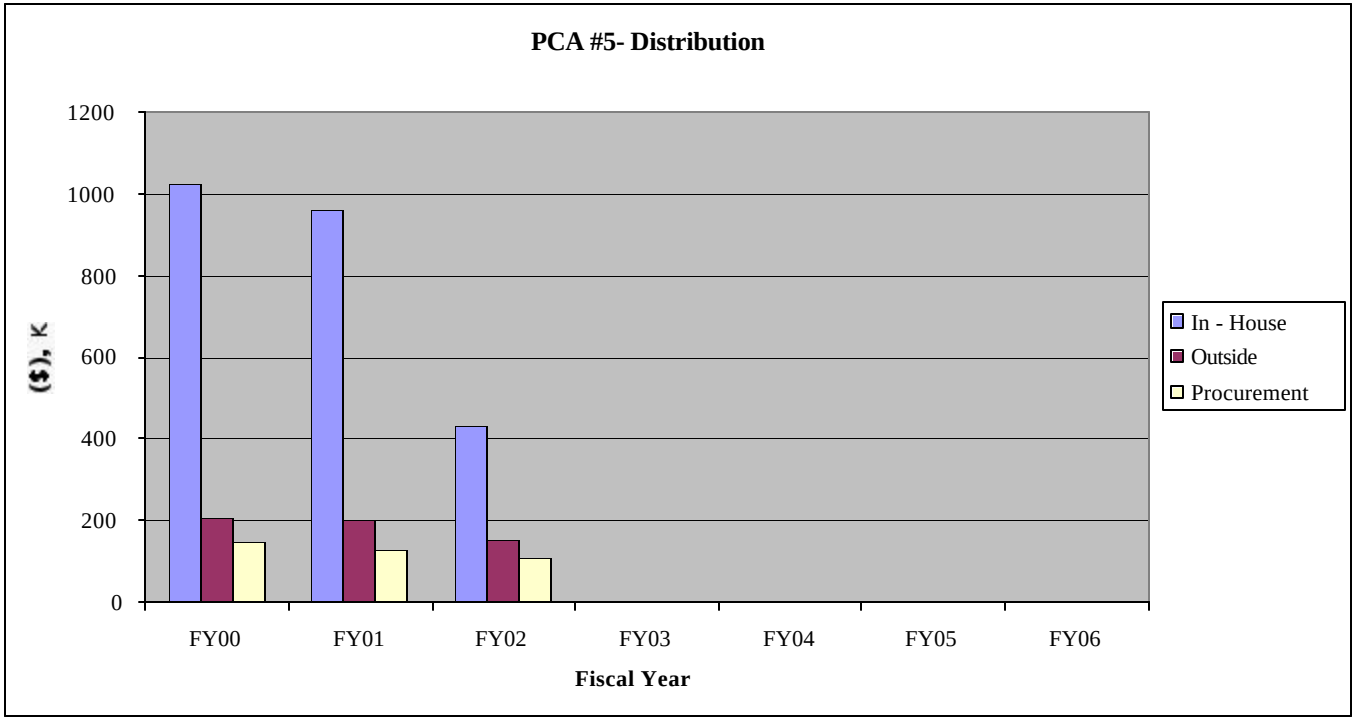
Budget Profile by WBS for PCA 5



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	146	142	67	0	0	0	0
Engineering	196	417	263	0	0	0	0
Applications & Research	180	199	100	0	0	0	0
Hybrid Networking	725	461	200	0	0	0	0
Technology Transfer	132	73	60	0	0	0	0

PCA 5: Integrated HPCC Technologies

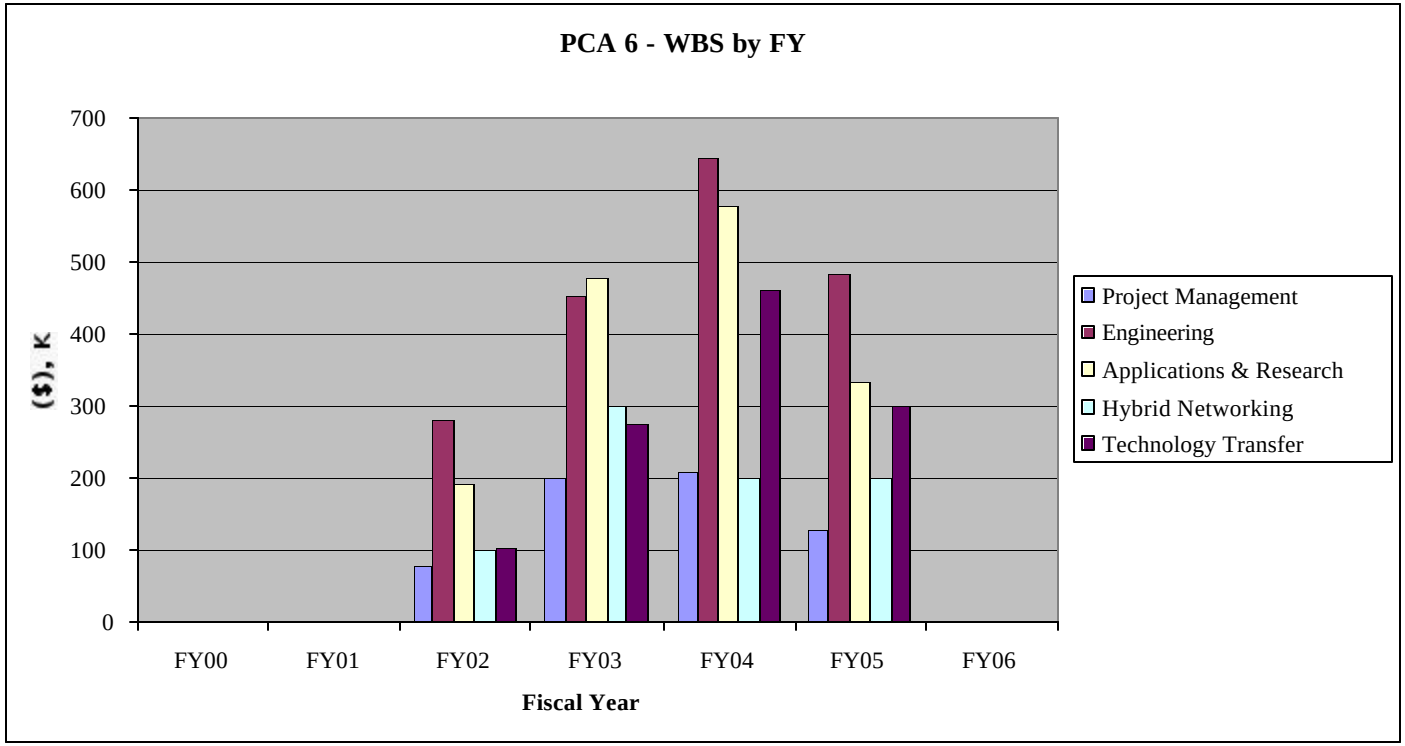
Budget Profile by Distribution for PCA 5



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	1024	959	435	0	0	0	0
Outside	209	205	152	0	0	0	0
Procurement	146	128	104	0	0	0	0

PCA 6: Significant Engineering, Scientific and Educational Impacts

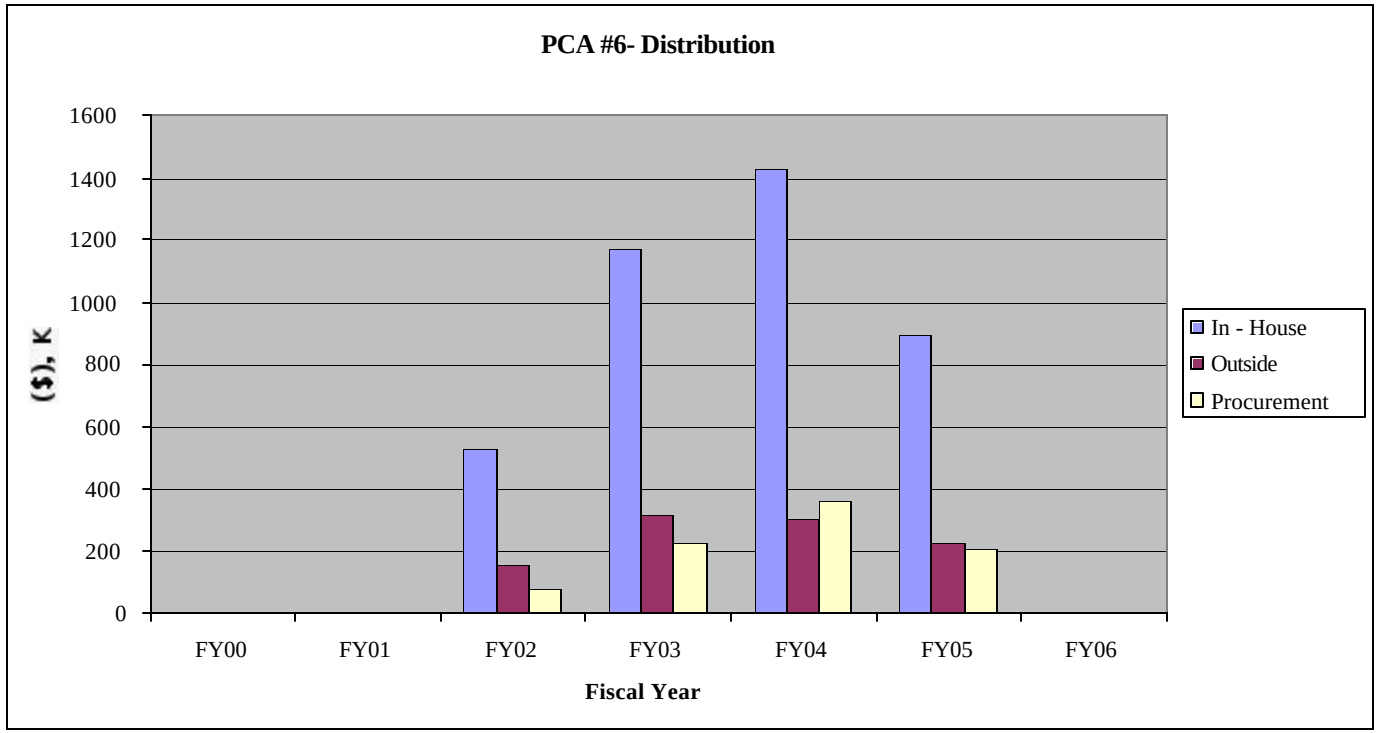
Budget Profile by WBS for PCA 6



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0	0	79	201	208	128	0
Engineering	0	0	281	454	644	483	0
Applications & Research	0	0	193	477	577	335	0
Hybrid Networking	0	0	100	300	200	202	0
Technology Transfer	0	0	104	276	461	301	0

PCA 6: Significant Engineering, Scientific and Educational Impacts

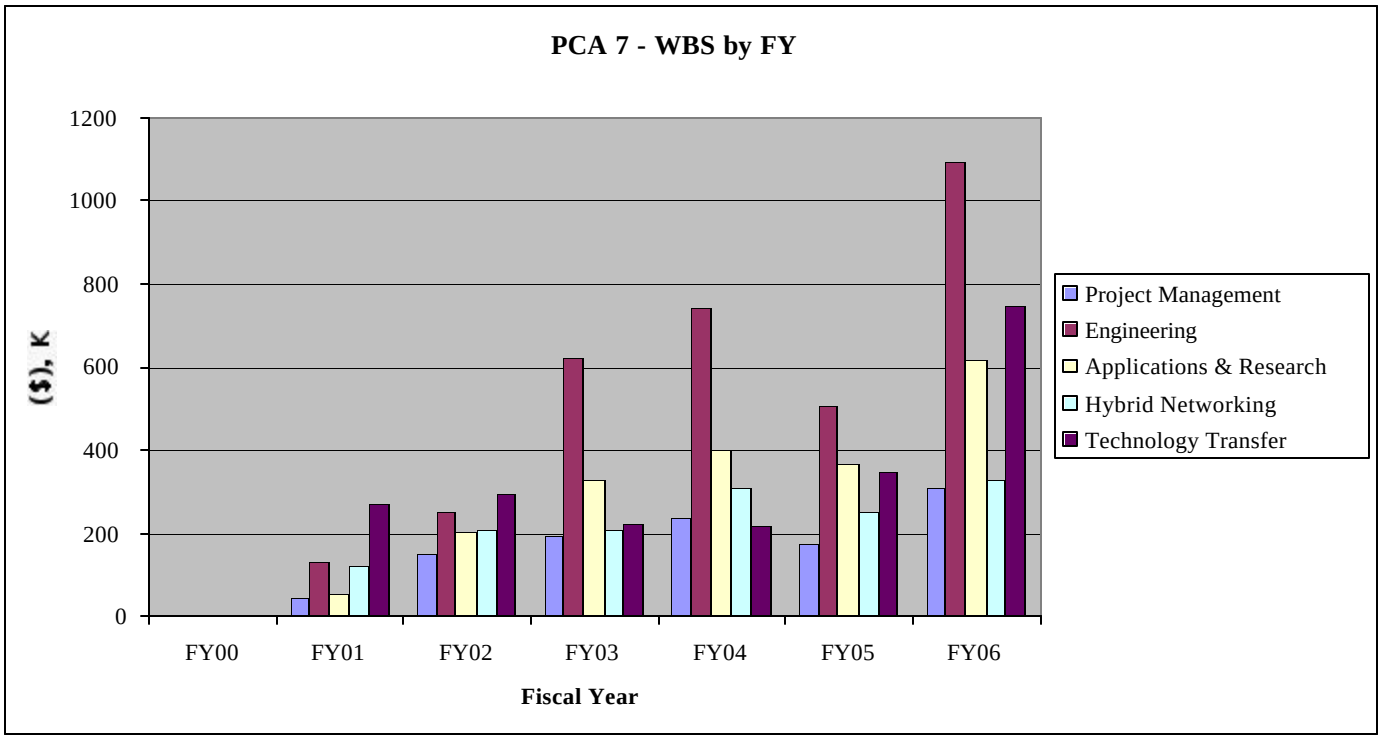
Budget Profile by Distribution for PCA 6



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	0	0	529	1167	1428	891	0
Outside	0	0	152	313	300	229	0
Procurement	0	0	76	229	361	201	0

PCA 7: Sustainable and Widespread Customer use of HPCC Program Technologies

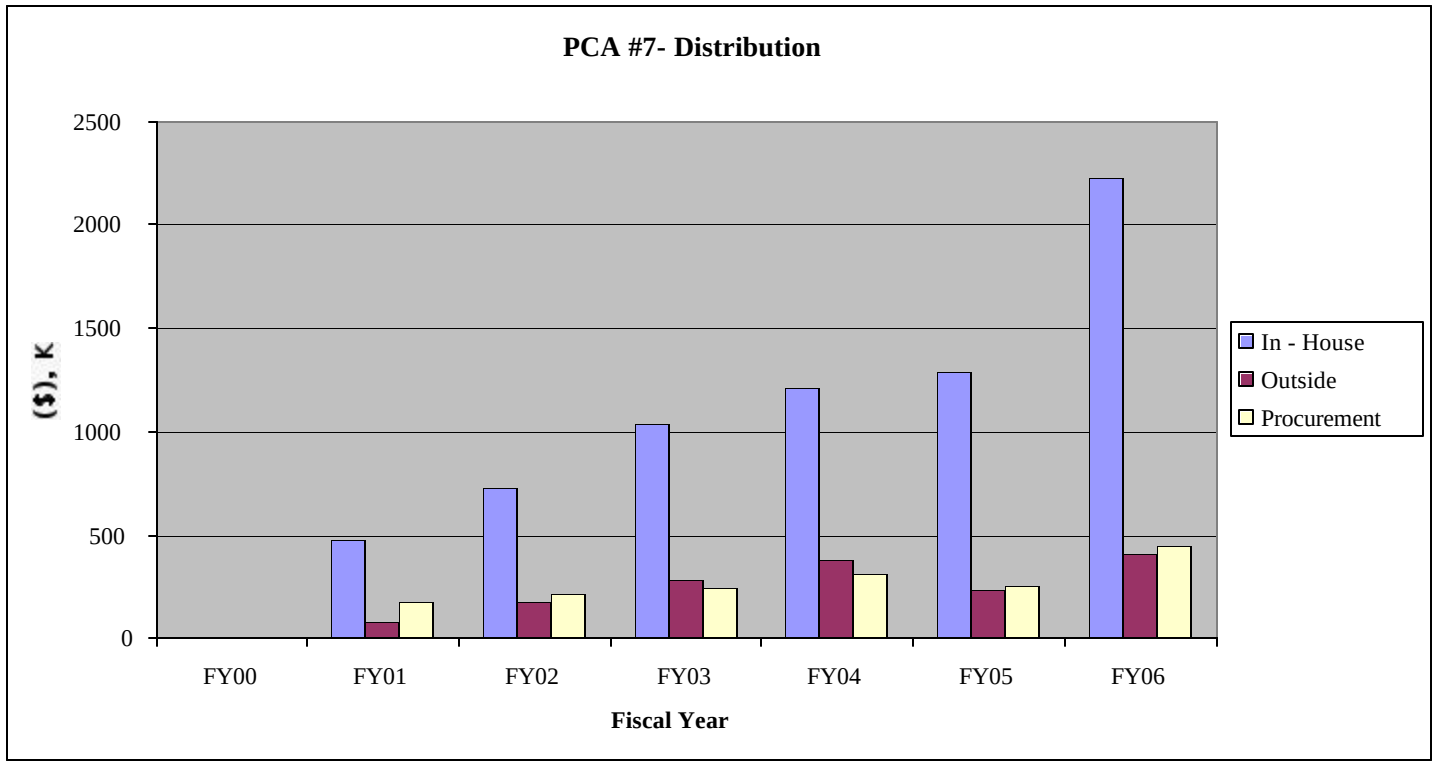
Budget Profile by WBS for PCA 7



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
Project Management	0	45	148	194	238	176	311
Engineering	0	132	251	621	745	507	1091
Applications & Research	0	54	206	332	401	367	619
Hybrid Networking	0	119	211	211	306	250	331
Technology Transfer	0	272	292	221	220	351	748

PCA 7: Sustainable and Widespread Customer use of HPCC Program Technologies

Budget Profile by Distribution for PCA 7



	FY00	FY01	FY02	FY03	FY04	FY05	FY06
In - House	0	478	727	1038	1207	1288	2235
Outside	0	74	173	291	383	229	417
Procurement	0	170	208	250	320	261	448